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Errata

Page 82, line 10, for '*Pinus sylvestrus*' read '*Pinus sylvestris*.'
Page 82, line 13, for '*Frittilaria*' read '*Fritillaria*.'
Page 82, last line, for 'aporophytic' read 'sporophytic'.
Page 83, line 2, for '*Entyloma Nympheae*' read '*Entyloma Nymphaeae*'.
Page 129, lines 4 and 10, for '*Acanthostigma parasitica*' read '*Acanthostigma parasiticum*'.
Page 141, line 22, for '*Uromyces houstoniatum*' read '*Uromyces houstoniatus*'.
Pages 188, 192, 213, 216, 217, 227, 229, for '*Lamprothamnus alopercoides*' read '*Lamprothamnus alopecuroides*'.
Page 233, after line 21, insert, coördinate with 'Leaves creno-serrate; summer-shoots tomentose', 'Leaves serrate or dentate, never creno-serrate; summer-shoots glabrous or tomentose'.
Page 238, line 4 from bottom, for '*Tilis*' read '*Tilia*'.
Page 245, line 6, for '*T. Michanxii*' read '*T. Michauxii*'.
Page 246, line 2, for '*T. Carolinians*' read '*T. Caroliniana*'.
Page 247, add foot-note '[6] Ashe, Bull. Charleston Mus. 32. 1925'.
Page 252, line 2 from bottom, for '*P. virides*' read '*P. viridis*',
Page 312, line 21, for '**M. giganteum**' read '**M. gigantea**'.
Page 325, lines 12, 35, and 36, for '*Nuttallii*' read '*Nuttallianus*'.
Page 327, line 12 from bottom, for '*A. austrina*' read '*H. austrina*'.
Page 332, line 2, for '*H. asprella*' read '*H. asperula*'.
Page 335, line 5, for '*Experanzae*' read '*Esperanzae*'.
Page 337, lines 9 and 21, for 'Monterrey' read 'Monterey'.
Page 338, line 25, for '*Commelina banghalensis*' read '*Commelina benghalensis*'.
Page 505, line 7 from bottom, for '*Conocephalus ovalus*' read '*Conocephalus ovatus*'.

Zostera marina latifolia: ecad or ecotype?

WILLIAM ALBERT SETCHELL

Zostera marina L. is undoubtedly a widespread species, ranging through many seas and many waters of different temperature relations, both as to range and as to degree, as well as to variety of seasonal maxima and minima. Ostenfeld gives a wide distribution for *Zostera marina* L. in both the north Atlantic (including the Mediterranean) and in the north Pacific oceans.[1] On the Pacific coast of North America, he gives its distribution as extending from southern California to Alaska.[2] There is, however, a discontinuity in the distribution of the *Zostera* variants on the west coast of North America which is puzzling and worthy of note. To the north (Unalaska, in the Bering Sea, and probably elsewhere in Alaska) what seems to be the typical plant similar to that of eastern North America and Europe occurs as it does also in the southern portion of the range (at least at San Diego, California), but between these two divisions of the coast (from southern Vancouver Island to Santa Barbara and probably to San Pedro) occurs a larger plant, with broad leaves of an aspect different from the usual form of Europe and of the Atlantic coast of North America.

The first to call attention to the broad leaved plant of the Pacific Coast of North America was Thomas Morong (Bull. Torrey Club **13**: 160. 1886) who named it *Zostera marina* var. (?) *latifolia*. The type specimen was collected cast up on the shore at Santa Barbara, California. He described the leaves as 5–12 mm. wide, 10–13 nerved with 7–8 striae between the nerves, and the fruits 4–5 mm. long by 3 mm. thick and with about 25 longitudinal ribs. Morong later on (Mem. Torrey Club **3**: 63. *pl. 71.* 1893) raised his variety to a species, *Zostera latifolia* Morong, and extended his description. At this time, he described the

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[1] Ostenfeld, C. H. Sea grasses. Report on the Danish Oceanographical Expeditions 1908–1910 to the Mediterranean and Adjacent Seas **2**^{K2}: 16. 1918.

[2] Ostenfeld, C. H. On the geographic distribution of the sea grasses. Proc. Roy. Soc. Victoria **27**: 188. 1914.

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root stalks as being stout and 8–10 feet long, the leaves as 2–4 feet long, and the fruit as having 20–25 longitudinal ribs.

In 1891, however, Sereno Watson (Proc. Amer. Acad. **26**: 131) described two new species of *Zostera* from the Pacific coast. The one, *Z. oregana* Watson, has slender root-stalks, narrow leaves (1.5–2 lines broad and rather faintly 3-nerved), spathes without a terminal appendage, and fruit with 16 longitudinal ribs. Morong (*loc. cit.*, p. 62) thinks that this species of Watson is *Z. marina*, that is as not belonging to his *Z. latifolia.* It is interesting to note here that Morong describes *Z. marina* as having 20 longitudinal ribs on the fruit and very correctly suggests that the spathe of Watson's *Z. oregana* has simply lost its terminal appendage, as often happens in older specimens of *Z. marina.* The type came from the mouth of the Columbia River.

The *Zostera pacifica* Watson is founded on the same general set of specimens as Morong's *Z. marina* var. *latifolia* and agrees in general, as to description, with Morong's statement. Watson, however, states that the 'seed' is 'not evidently striate, but appearing under the microscope very finely transversely striolate.' No type is designated, but specimens are quoted ranging from Puget Sound to Santa Barbara.

An examination of Watson's type specimens in the Gray Herbarium convinces me that both his species are the same and belong to the familiar broad leaved plant of the middle region of the Pacific Coast of North America. *Zostera oregana* Watson is an older flowering stem whose spathes have lost the terminal segment, and *Z. pacifica* Watson shows longitudinal striae of the proper number (about 20) on the immature seeds (still enclosed in the utriculoid ovary wall). It seems clear that both are closely related to *Zostera marina* L. and may be designated as *Z. marina* var. *latifolia* Morong, or simply as the *latifolia* form of *Z. marina*.

Since the *latifolia* form is frequent in the San Francisco Bay region (although not conveniently accessible to those who live in Berkeley), I have attempted to obtain as considerable collections and data as possible. The chief assistance has been obtained through Mr. Harold E. Parks and Miss Monica Dietrich. Mr. Parks, particularly, has collected stages in development throughout several years in connection with observations on the temperature of water and air, and Miss Dietrich has examined the various materials collected on the central Pacific coasts, and compared her results with those obtained from an examination of a great amount of material collected through successive years on the Atlantic coast of North America from Beaufort, North Carolina, north to the fjords on the Greenland coast in the neighborhood of Godthaab.

The results of Miss Dietrich's examinations may be summarized in the following comparisons:

Character	*Atlantic*	*Pacific*	*No. of plants*
Length of flowering plant	1.5–4 feet	3–10 feet	100+
Number of branches of flowering plant	1–5	1–21	100+
Width of leaves	5/32 inches	5/16 inches	100+
Number of nerves in leaves	3	5–7	100+
Longitudinal ribs on seed coat	16–18	17–22	100+

From the summary of Miss Dietrich's examination of somewhat over 100 plants from each coast of North America, it seems to be clearly indicated that the differences between *Zostera marina typica* and *Z. marina latifolia* may be considered quantitative, and probably clearly so. In breadth (and length also, although no measurements are given) as well as in number of nerves, the leaves of the *latifolia* form exceed (with slight overlapping) those of the typical form. The same is true of the number of internodes (usually 7 in f. *typica* and much over that and up to 30 or thereabouts in f. *latifolia*). In number of branches of the flowering shoot, f. *latifolia* much exceeds f. *typica*. These might be expected as within the limits of variation in the species, but the excess of longitudinal ribs on the seed coats of f. *latifolia*, which barely overlap with those of f. *typica*, seems to indicate a possible qualitative difference as well, being at least a quantitative difference of another type than length and breadth relations, although the number of internodes and number of nerves, and consequent opportunity for greater length and number of branches, may possibly also be thought of as qualitative.

As far as I can determine, however, the characters of number or size are the only characters in which f. *latifolia* differs from the f. *typica*. Furthermore, there are occasionally observed, outside the range of typical f. *latifolia*, individuals with broader leaves, suggesting other plant dimensions similar to it, but such individuals have neither been noted frequently nor carefully studied.

The occurrence of such a striking variant as the *latifolia* form or variety, along as extended a coast as that from Vancouver Island to Santa Barbara, leads to the question of environmental conditions and particularly those of climatic relations, in the case of both f. *typica* and f. *latifolia*. The two forms of *Zostera marina* exist under very similar edaphic and biotic complexes, so far as is evident, and the climatic complex differs chiefly in the temperature factor. It is this factor and its possible influence that presents itself for investigation in the two cases.

I have already indicated (Science **56**: 575–577. 1922) the results of a general study of the temperature relations of *Zostera marina*. The awakening of its dormant vital activities occurs at approximately 10° C. Its vegetative processes proceed with the gradual but comparatively rapid, rise of the temperature of the water until at 15° C. the leaves are well expanded, the erect stem of the season is well developed, and the flowers are formed. As the temperature rises over 15° C., anthesis occurs (protogynous), pollination takes place, and fruit is formed and matured. If the temperature rises above 20° C. and remains there even for a few days, the erect stem of the year dies and with its own segments of rhizome breaks away from the rest of the prostrate portion of the plant and floats, scattering its fruits as it decays, depositing them mostly in protected shallow muddy areas where later they are grubbed up by ducks and geese, whose crops during the spring migration are frequently full of them. Along the Atlantic coast of North America the seasonal temperature range for the water for that portion known to be inhabited by f. *typica*, goes well below 10° C. in the late winter months, and up to or well above 20° C. in the later summer and early autumn months. Even in the most northern portion of the range, the inner fjords running in from Godthaab, Greenland, we may suspect the temperature of the water rising well above 15° C., since the eel grass comes into anthesis, although the few temperatures at our disposal do not indicate so high a temperature. There are complete records for f. *typica* and its temperature relations for two years from Beaufort, North Carolina, and Woods Hole, Massachusetts made by the United States Bureau of Fisheries, and fairly complete records for the season of greatest growth, anthesis, and fruiting from the coasts of New Jersey, outer coast at Newport, Rhode Island, and inner Narragansett Bay region at Lee's River, Massachusetts. There are suggestive records from Mt. Desert Island, Maine, and St. Andrews, New Brunswick. More details of these will be given in a later paper. The general trend of all these observations along the Atlantic Coast of North America indicates that the entire growing period at each of the localities mentioned is about two and not over three months. At Beaufort, North Carolina, these are the months of March and April; on the sheltered inland waters of New Jersey, probably April and May; at Lee's River, Massachusetts, May and June; extending at Woods Hole, Massachusetts, from May into early July; on the outer coast at Newport, Rhode Island, June and July; and on the Maine coast, July and August.

Observations on the f. *latifolia* in beds at Paradise and Kyle coves on the Marin County shore of the Bay of San Francisco, carried out by Mr. H. E. Parks, indicated a much slower rise of temperature from about 9° C. in February to about 18° C. from April to late September (varying from 15° C. to 18° C.) and occasionally going up possibly to nearly 20° C. when influenced by seepage or outflow from shallow lagoons, declining soon after the last week of September to 12° C. and then gradually to 10° C., reaching 9° C. and 10° C. the last of January.

Growth from leaf buds starts promptly at about 10° C. (early February) and at a little above that plentiful seedlings were obtained (early February). At about 15° C. anthesis begins, but the ovaries appear to blast if the temperature does not rise. This is generally about the first week in April. In the warmer parts of the bed (those most subject to seepage of warm water from a lagoon) the anthesis proceeded rapidly and fruits set, but in the colder portions of the bed (washed by an outer current) anthesis was backward or the young fruits blasted. From the temperatures of the waters, it may be presumed that similar relations hold throughout the range of f. *latifolia*.

The temperature relations of f. *latifolia* are seen to be very different from those of f. *typica*, the rest of the environmental complex being, so far as can be estimated, very similar if not identical. The temperature never rises above 20° C., the upper temperature limit of activity for both forms, and goes only a degree or so below 10° C., its lower limit of activity. The rise of temperature is somewhat slower in the case of the waters inhabited by f. *latifolia*, and seemingly the development of the plant as a whole, and particularly of the fruits, proceeds more slowly and through a period several times as long as is the case in f. *typica*.

It seems possible, therefore, that the quantitative differences which separate f. *latifolia* from f. *typica* may be due directly or indirectly to the peculiar temperature relations of its environment, and that f. *latifolia* may simply be an ecad or environmental form induced by the different intensity and duration variables of the temperature factor of its environment. Whether it be an ecad in the reversible sense of Clements, (Plant Physiology and Ecology, pp. 192, 193, 1907) or an ecotype in the sense of Turesson (Hereditas 4: 172. 1923) can of course only be determined by culture from seed or by transplant experimentation, a test not at present possible for me to carry through. These methods alone are likely to determine whether any difference in the genetic constitution exists between the two sets of forms.

The variation in morphological characters between the two varieties of *Zostera marina* is clearly associated with a difference in intensities, rapidity of rise and fall, and seasonal variation in the temperature factor, and this general relation is certainly suggestive of some causal connection between the environmental factor and the quantitative morphological differences, but as to whether there has been a genetic change or simply a variable genetic response must be left for future study.

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On certain fossil cones from the Pacific Coast

FLORA MURRAY SCOTT

Widespread and dominant as are the Conifers in the vegetation of the present day, of their early history comparatively little is known. The discovery of gymnosperm wood in various degrees of petrifaction points to a relative fixity of anatomical structure. Of the reproductive organs of the ancestral forms, however, we can as yet say very little. Looking at a present day Conifer, it is of course obvious that the cone of such a forest tree runs but a very slender chance of being conveyed entire to a near-by stream, thence onward to a convenient lake, an area of sedimentation, and of fossil formation. Against such a possibility also there militates the cone habit of certain forms. The cone of the genus *Pinus*, for example, opens to shed its seeds, but remains as a rule, attached to the parent branch for a varying length of time. In the genus *Abies*, on the other hand, the cone disintegrates entirely, scales and seeds being shed simultaneously. Interpreting the past in the light of the present, the paucity of the fossil record appears therefore to be less remarkable. The fossil cones, to be presently described, belong to the geological collection of Stanford University. They were placed at my disposal by Dr. J. P. Smith. To Dr. Smith, and to Dr. LeRoy Abrams of the Department of Botany, I wish to express my very sincere thanks for criticism and assistance in the identification of the following forms.[1]

1. *Pinus muricata* Don. The Santa Clara formation of the Coast Range, consisting of coarse gravels, sands, sandy clays, locally lignitic, of fresh water origin (Branner, 3) in addition to a varied fauna, preëminently recent in character, has also yielded a unique Pliocene flora. To the list of plants which Hannibal (5) has described from this formation, there may be added the gymnosperm *Pinus muricata* Don (collected by L. H. Dougherty).

Embedded in the grayish yellow sandstone of the plant beds at Portola was found the base of a pine cone, completely carbonized, in form somewhat flattened, but otherwise perfectly preserved. The cone was unfortunately abruptly broken off, the outcrop on the cliff-face having been cut back during road construction. On splitting the sandstone, the carbonized fragment became loosened and dropped out, leaving a perfect mould of both sides. The specimen was 2.5 cm. long and was flattened to a breadth of 4. 5 cm. Judging from the general outline of the part preserved, the cone was originally 5–6 cm. in length.

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[1] Photographs of all the specimens discussed in this paper, at best very difficult subjects, were submitted with the manuscript for publication, but at the suggestion of the editor were withdrawn, as being inadequate for reproduction without much re-touching.—EDITOR.

In its general appearance, its asymmetry, and the elongated, sharp-pointed, and still unopened scales, it coincides entirely with the description of the cone of *Pinus muricata*.

> Cones 5–7 cm. long, . . . unsymmetrical, . . . by the much enlarged outer scales, which are prolonged into prominent knobs armed with a stout elongated spine, remaining closed for many years. . . . (Abrams, 1).

The asymmetry is peculiarly well seen in the mould of the two sides of the fossil, and while the actual spine is slightly less obvious on the tip of the carbonized scale, yet its position is perfectly apparent throughout.

The genus *Pinus* in North America dates at least from Jurassic, the leaves of *Pinus Nordenskiöldi* Heer being described from strata of that age in Douglas County, Oregon (Knowlton, 6). Thereafter, by the time of the laying down of the Cretaceous (Raritan and Magothy) of the Atlantic states, *Pinus*, to judge from the numerous species then in existence, was already a successful genus, and has so continued until the present day.

The Coniferae, as a whole, form the main vegetation of the Western Divide of the Coast Ranges of Western America. While certain species range throughout the entire forest belt, there are others which are notably restricted in occurrence, and of such is the present *Pinus muricata*.

> **Pinus muricata**, a maritime species of the Transition and Upper Sonoran Zones, most abundant and best developed along the coast from Inglenook, Mendocino County, to Point Reyes, California, forming an almost continuous belt. Southward occurring in small, widely separated groves, Point Pinos Ridge near Monterey, Pecho Mountains, San Luis Obispo County, and Santa Cruz Island; re-appearing again in a modified form (var. *Anthonyi* Lemmon) between Ensenada and San Quentin, Lower California, and on Cedros Island (Abrams, 1).

Such discontinuity in distribution probably indicates that *Pinus muricata* is a waning species; that, at one time, when its occurrence throughout the Coast Ranges was uninterrupted (a probable hypothesis supported by the finding of the present specimen) it possibly occupied a more important place in Coastal Forest vegetation.

2. *Pinus* sp. (collected by O. E. Paine). It has already been remarked that the genus *Pinus* dates at least from the Jurassic period. Of the fossil Coniferae it is one of the most widely occurring genera. On the Pacific Coast it is repeatedly recorded from British Columbia (Penhallow, 8) and from California (Knowlton, 6). The majority of the fossils, however, consist of leaf and branch impressions. Cones are but rarely reported.

In the Miocene deposits thirteen miles north of Santa Barbara, California, were found the two cones considered here. Of these, one is fairly complete. The fossil is conical in shape and markedly asymmetric. It measures about 10 cm. in length and 5.5 cm. in diameter. Before calcification it had already undergone considerable decay and no traces of the axis remain. In its stead the hollow central space is lined with irregular and somewhat fibrous calcite.

In asymmetry, in the form of the scales, thin at the base, and expanded distally into 'prominent transversely flattened knobs' (Sargent, 9), the cone appears to resemble fairly closely that of *Pinus attenuata* Lemmon, although the diagnostic spines of this species are not preserved.

The present distribution of *Pinus attenuata* Lemmon extends from Oregon to the San Bernardino mountains, so that, if the identification with *Pinus attenuata* should hold, the discovery of the fossil indicates the very prolonged continuation of a successful species.

3. *Pseudotsuga* sp. In marked contrast to the genus *Pinus*, the genera *Pseudotsuga* and *Abies* (to be presently discussed) are almost entirely absent from the fossil record.

The Miocene of British Columbia (Penhallow, 8) and of Alberta (Knowlton, 6), the Pliocene of the Santa Cruz mountains, California (Hannibal, 5), and the Pleistocene of Humboldt County, California, and of Mystic Lake, Montana (Knowlton, 6) have yielded the only traces of this, today, very widespread genus.

The present specimen, a finely preserved cone, was found in the Oligocene (?) or Lower Miocene (?) of Nitinat Lagoon, Vancouver Island (loc. N. P. 142: collected by H. Hannibal).

The cone is completely petrified and has been sectioned and polished. It is elongated-elliptical in shape and measures 7 cm. in length and 3.5 cm. in diameter. Springing almost at right angles from the central axis there arise bract, thin and flattened scale, and seed. In section the cone bears a striking resemblance to that of the present day form, *Pseudotsuga mucronata* Sudw. This species today ranges from the Skeena River as far south as Northern Mexico (Sargent, 9).

4. *Abies* sp. (N. P. 253: collected by H. Hannibal.) Of the geological history of the genus *Abies*, widespread today throughout the northern hemisphere, and abundant along the Pacific Coast, remarkably little is known. From the Pleistocene of Ontario, Canada, *Abies balsamea* (Linne) Miller is reported, and from the Kenai formation of Alaska, *Abies* sp. (Knowlton, 6). From the Trias onwards there occur numerous *Abies*-like twigs and leaves, in a more or less imperfect state of preservation. These bear a sufficient resemblance to the genus *Abies* to warrant the name *Abietites*. The traces consist mainly in leaf impressions. The lower Cretaceous (Arundel and Patapsco) of Maryland (Berry, 2) has however yielded numerous cones of *Abietites macrocarpus* Fontaine. These again are but poorly preserved.

For the rest a few isolated specimens of *Abietites Ernestinae* Lesquereux (7) and of *Abietites* sp. (Fontaine 4) appear to form the sum total of the remains of *Abies*-like cones.

That complete cones of *Abies* do not occur as fossils is doubtless due to the fact that they do not fall from the tree when mature. The cone-scales fall off separately, leaving on the branch the upright axis.

The present specimen from the Oligocene (?) or Lower Miocene (?) of Vancouver Island is therefore of interest.

The cone measures about 10 cm. in length and 5 cm. in diameter. Though but roughly preserved (in dull brown friable sandstone) the elliptical form, the blunt apex, with wide, closely imbricated scales, are unmistakably diagnostic of the genus *Abies*.

In general appearance it resembles fairly closely the species *Abies concolor* Lindley, which today ranges from the Rocky Mountains of Colorado to the Coast Ranges of California and northwards to Oregon.

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Literature cited

1. **Abrams, LeRoy.** An illustrated flora of the Pacific States **1**:60. Stanford Univ. Press, 1923.
2. **Berry, E. W.** Systematic paleontology of the Lower Cretaceous Deposits of Maryland. Gymnospermae. Maryland Geol. Surv. Lower Cretaceous 370–451. *pl. 66, 67.* 1911.
3. **Branner, J. C., Newson, J. F., & Arnold, R.** U. S. Geol. Surv. Geol. Atlas of the U. S. Santa Cruz Folio 163: 6. 1909.
4. **Fontaine, W. M.** Notes on some fossil plants from the Trinity division of the Comanche series of Texas. Proc. U. S. Nat. Mus. **16:** 277. *pl. 43.* 1893.
5. **Hannibal, H.** A Pliocene flora from the Coast Ranges of California. Bull. Torrey Club **38:** 329–342. *pl. 15.* 1911.
6. **Knowlton, F. H.** Catalogue of the Mesozoic and Cenozoic plants of North America. U. S. Geol. Surv. Bull. 696: 1–815. 1919. (This bulletin contains a complete list of references.)
7. **Lesquereux, L.** Cretaceous flora. Rep. U. S. Geol. Surv. Terr. **6:** 49. *pl. 1, f. 7.* 1874.
8. **Penhallow, D. P.** Report on the Tertiary plants of British Columbia collected by Lawrence M. Lambe in 1906. Canada Dept. Mines, Geol. Surv. Branch Publ. 1013: 68. *f. 19.* 1908.
9. **Sargent, C. S.** Manual of the trees of North America. Boston and New York, 1905.

Notes on Fabaceae—VIII

PER AXEL RYDBERG

HAMOSA

The genus was constituted by Medicus, (Vorl. Churpf. Phys. Ges. 2: 376. 1787), and based on *Astragalus hamosus*, *A. glyciphyllus*, and *A. trimestris*, of which the first must be taken as the type. This is an annual European species with narrow arcuate pod, subterete in cross-section, perfectly 2-celled, with valves of a firm texture. *A. trimestris* evidently belongs to the same group, but the pod of *A. glyciphyllus* is quite different. The American species known in 1866, were included by Gray in his section MICRANTHI, except *Astragalus succumbens*, which was made a section by itself, *A. tener* of which the pod was unknown, and *A. Lindheimeri*, which was misplaced.

- Keel not beaked.
  - Perennials with a cespitose rootstock or caudex.
    - Corolla 1–2 cm. long (rarely 7–10 mm. long); pod linear or narrowly oblong, rather abruptly acute at each end, spreading.
      - Plant villous or pilose; calyx cylindric-campanulate, the tube longer than the teeth.
        - Pod glabrous, strongly flattened... 1. SUCCUMBENTES
        - Pod pubescent, less strongly flattened........................ 2. MALACAE
      - Plant strigose or glabrate; calyx campanulate.
        - Low, pulvinate-cespitose, acaulescent, silvery plants; wings 2-lobed. 3. SCAPOSAE
        - Taller, leafy-stemmed, usually canescent or glabrous plants; wings entire......................... 4. TRIQUETRAE
    - Corolla 5–7 mm. long, flowers in dense racemes; pod broadly oblong or lance-oblong, gradually acute, reflexed................ 7. HARTWEGIANAE
  - Annuals with few-flowered racemes and mostly narrowly linear pods...................... 5. LEPTOCARPAE
- Keel produced into a porrect beak................. 6. ACUTIROSTRES

1. SUCCUMBENTES

This group was constituted by Dr. Gray as a section of *Astragalus*. It is characterized by the following features: low and stout cespitose perennials, with pilose stems amd leaves, short dense racemes, rather large flowers, fully 2 cm. long, cylindro-campanulate pilose calyx, the lobes being less than half as long as the tube, broad, linear-oblong, slightly falcate, glabrous pods, 3–4 cm. long, 5 mm. broad, deeply sulcate on the lower suture, compressed, inverted Y-shaped in cross-section, membranous, sessile. It is represented by only one species, which Jones united with the MALACAE.

1. **Hamosa succumbens** (Dougl.) Rydb. *Astragalus succumbens* Dougl.; Hook. Fl. Bor. Am. **1**: 151. 1831. *Astragalus dorycnioides* Dougl. (D. Don, Gen. Hist. **2**: 258. 1832) is generally regarded as a synonym of this. The description agrees fairly well, except that the calyx is described as 'smooth.'

OREGON: *Howell*, in 1880; Alkali, *Howell*, in 1882; Pendleton, *Griffiths & Hunter 6;* without locality, *Wilkes Expedition 1018;* Baker City, *Nevius* in 1875; Warner Valley, *Eggleston 6985, 6989.*—WASHINGTON: Walla Walla, *Douglas; Lyall* in 1860; *W. Brandegee 719;* Klickitat Co., *Cotton 1342;* Umatilla, *Cusick 586;* Kluck, *Howell*, in 1879.—CALIFORNIA: Butte County, *Eggleston 7335*.

2. MALACAE

This group was proposed by Jones as a section MALACI of *Astragalus*. *A. malacus* and *A. Andersonii* had been included by Watson as anomalous species of the section MICRANTHI, which Sheldon remodeled and renamed as EREMITICUS. As constituted by Jones the section was very unnatural, containing besides *A. malacus* and *A. Layneae*, also *A. succumbens* mentioned above, *A. Parryi*, and *A. feensis*. *A. Parryi* has no close relationship to *A. malacus*. Nor do I think that *A. feensis* should be included Gray placed *A. Andersonii* next to *A. malacus*, but Jones placed it in HAMOSI next to *A. Congdoni*. The group consists of stout cespitose perennials, with rather middle-sized flowers about 1.5 cm. long, rather broad, oblong or linear, falcate pods, with long loose pubescence, slightly sulcate on the lower suture and narrowly obcordate in cross-section.

Calyx black-hairy; pod 2–4 cm. long; corolla purple
  or tipped with purple.
  Pubescence spreading; pod moderately arcuate,
    acute or short-acuminate.................. 2. *H. malaca*

Pubescence appressed or ascending.
  Pod strongly arcuate, long-acuminate, 3–4 cm. long.............................. 3. *H. Layneae*
  Pod straight or slightly arcuate, 2–2.5 cm. long, abruptly acute.................... 4. *H. Minthorniae*
Calyx white-hairy; pod less than 2 cm. long; corolla white or ochroleucous; pubescence villous.......... 5. *H. Andersonii*

2. HAMOSA MALACA (A. Gray) Rydb. In this species the calyx-tube is comparatively long and in that respect the flower approaches that of the genus *Xylophacos*. The fruit, however, is that of a typical *Hamosa*, except that it is broader and long-pilose. Jones (Rev. Astrag. 227. 1923) made *Astragalus obfalcatus* a variety of *A. malacus*, and it may be so regarded.

NEVADA: Carson City, *C. L. Anderson 26, 307, 285; Shockley 353;* Eagle Valley, *Stretch 152, 224;* Trinity Mountains, *Watson 259;* Washoe County, *Heller 9698a, 9574;* Empire City, *Jones 3838;* Virginia City, *Bloomer*, in 1863; Mica Springs, *Jones 5036a;* Carson City, in 1897.—CALIFORNIA: *Lemmon 63;* Lassen County, *Mrs. Bruce 2214;* Owens Valley, *Horne; Jones*, in 1897; San Bernadino Mountains, *Parish 1275* (?); Modoc Co., *Mrs. Manning*, in 1907; Howey Lake, *Brandegee*, in 1892; Mojave Desert, *Grinnell*, in 1907; Calico, *Lemmon*, in 1884.—OREGON: Malheur County, *Leiberg 2090;* Stein Mountain, *Howell;* Warner Valley, *Eggleston 6989, 6985;* McDowell Creek, *7052*.—IDAHO: Weiser, *Jones 6226*.

3. **Hamosa Layneae** (Greene) Rydb. *Astragalus Layneae* Greene, Bull. Calif. Acad. **1**: 156. 1885. This species is evidently most closely related to the preceding, though the habit, pubescence of the leaves, and shape of the pod remind much of those of *Xylophacos amphioxys*, for which it has been mistaken. *Heller 7669* has larger and less hairy leaflets and larger flowers about 2 cm. long. The specimens are in flower only. Bigelow's specimens were described as *Astragalus Fremontii* var. (Pacific Railroad Rep. **4**: 80. 1857).

CALIFORNIA: Mojave Creek, *Bigelow*, on Whipple Expedition; Darwin, *Jones*, in 1897; San Bernadino County, *Heller 7669;* Lee Mine, Inyo County, *S. W. Austin;* Mojave Desert, *Parish 1273*.—NEVADA: Rhyolite, *Heller 9668;* Las Vegas, *Gooding 2283*; Gold Mountain, *Purpus 5939*.

4. **Hamosa Minthorniae** Rydberg sp. nov. Perennial, prob-

ably cespitose; stems low, strigose and striate; leaves erect, 5–10 cm. long; stipules ovate, 7–8 mm. long; leaflets 11–17, obovate, 8–15 mm. long, 4–6 mm. wide, silky-canescent, rounded at the apex; peduncles 8–12 cm. long; racemes 6–10 cm. long; bracts lanceolate or lance-linear, 5–6 mm. long; calyx black-hairy, the tube 5–6 mm. long, the teeth subulate, 2 mm. long; corolla white, with a purple-tipped keel; banner obovate, 15 mm. long; wings much shorter, the blades oblong-falcate, with a large rounded auricle; keel-petals still shorter, broadly lunate, rounded at the apex; pod oblong, straight or slightly arcuate, 2–2.5 cm. long, 4 mm. thick and wide, shaggy-pilose, abruptly acute, obcordate in cross section.

Nevada: Vicinity of Pioche, Lincoln County, April 24, 1909, *Maud Minthorn 77* (type in herb. N. Y. Bot. Gard., duplicate in Univ. California); Kyle Cañon, *Tidestrom 9612*.

5. **Hamosa Andersonii** (A. Gray) Rydb. *Astragalus Andersonii* A. Gray, Proc. Am. Acad. **6**: 524. 1866. Watson placed this next to *Astragalus malacus*, where I am inclined to retain it on account of the spreading pubescence of the broad pod. Jones placed it in his section Hamosi next to *A. Congdoni*. It is true that in certain respects it is intermediate between the Malacae and the next group.

Nevada: Carson City, *Anderson 233; Heller 9816;* Empire City, *Jones*, in 1882; Reno, *Stokes*, in 1900; Eagle Valley, *Stretch*, in 1865; Hunter Creek Cañon, *Kennedy 1602;* Kings Cañon, *Baker 906;* Washoe County, *Heller 9768; Kennedy 2084; Watson 258;* Verdi, *Stokes*, in 1903.—California: *Lemmon 64;* Inyo County, Heller *8357;* Lone Pine, *Jones*, in 1897; Sierra Valley, *Lemmon 1089, 630;* Independence, *Matthews*, in 1877; Lassen Co., *Eggleston 6734, 6730*.

3. Scaposae

This group is characterized by the scapose habit, the silvery leaves, the short broad pod, and the broad, more or less 2-lobed wing-petals, the corolla in this respect resembling that of *Aragallus*.

Calyx-teeth subulate-lanceolate, more than half as long as the tube.......................... 6. *H. calycosa*
Calyx-teeth deltoid-lanceolate, about one-third as long as the tube.
  Leaflets 3–9, oval or obovate, 5–12 mm. long, inflorescence several-flowered............... 7. *H. scaposa*

Leaflets 7–11, oblong-oblanceolate, 3–4 mm. long, inflorescence 1–3-flowered, rarely 4-flowered.. 8. *H. manca*

6. HAMOSA CALYCOSA (Torr.) Rydb. This species was described as having ochroleucous flowers, only the keel being tipped with purple. This is apparently usually the case in the Nevada and California specimens. In the Wyoming, Idaho and Utah specimens the corolla is usually larger and often wholly purplish: this form was described as *Astragalus brevicaulis* A. Nels.

CALIFORNIA: Inyo Mountains, *Coville & Funston 1780.*—NEVADA: East Humboldt Mountains, *Watson 257;* Koalin Hills, *Stretch 267;* Mineral County, *Heller 10494;* Palmetto Range, *Purpus 5872.*—UTAH: Jugtown, Piute County, *Jones 5403;* Eureka, *Jones*, in 1891; Deep Creek and Detroit, *Jones;* Ephraim, *Tidestrom 1125;* Manti Forest, *Clos 6;* Loa, *Jones 5639j;* Salina Cañon, *5422, 5413a, 5412h;* Milford, *Stokes*, in 1903; Tintic, *Wooton*, in 1915; Ephraim, *Eggleston 10118.*—WYOMING: Fort Bridger, *A. Nelson 4601.*—IDAHO: Pocatello, *Mrs. Soth 44; Palmer 45; Macbride & Payson 3107.*

7. HAMOSA SCAPOSA (A. Gray) Rydb. This species is closely related to the preceding. Jones, perhaps correctly, regards it as a variety thereof. It is a larger plant, with more elongate inflorescence and short calyx-teeth. The corolla is usually purplish. *Astragalus candicans* Greene is a synonym of it.

COLORADO: McElmo Cañon, *Eastwood.*—NEW MEXICO: Aztec, *Baker 409;* Socorro, *Plank*, in 1895.—ARIZONA: *Palmer 100, 109;* Hell's Cañon, *Rusby 580;* Fort Huachuca, *Wilcox*, in 1893; Grand Cañon, *Miss Beckwith 92;* Fort Verde, *Mearns 297*, in 1888; Hackberry *Jones 4426;* Peach Springs, *Jones 63; Lemmon 3252;* Grand Cañon, *Macbride & Payson 944; Grant 74a;* Jerome Junction, *Tidestrom 897;* Oak Creek, *Purpus 8240;* Black Rock Spring, *Jones 5098n;* Pagumpa, *5098a.*—NEVADA: Pioche, *Maud Minthorn 10.*

8. **Hamosa manca** Rydb. sp. nov. Acaulescent tufted, cespitose perennial, with a short woody caudex; stems less than 1 cm. long; leaves 1.5–2 cm. long; stipules deltoid, 2 mm. long; leaflets 6–11, elliptic-oblanceolate, 2–4 mm. long, 1–2 mm. wide, acute or obtusish; silvery-canescent; peduncles slender, 2–5 cm. long; racemes 1- or 2- (rarely 3-) flowered; bracts

lanceolate, 1 mm. long; calyx campanulate, silvery-strigose, the tube 3–4 mm. long, the teeth deltoid, 1 mm. long; corolla about 1 cm. long, ochroleucous, the keel tipped with purple; banner broadly obovate, deeply notched; wings of about the same length, broad, 2-lobed at the apex; keel-petals broadly lunate, rounded at the apex; pod oblong-ovate, about 1 cm. long, and 4 mm. wide, sericeous.

Type collected in Clover Mountains, Nevada, near Death, July 24, 1908, *Heller 9163* (herb. N. Y. Bot. Gard.); apparently also in Charleston Mountains, Clark County, *Heller 11032*.

4. TRICARINATAE

This group constitutes also a part of Gray's section *Micranthi* of *Astragalus* and Sheldon's *Eremiticus*. It could be said to be equivalent to the main part of Jones' section *Hamosi*. Jones' name should not be adopted, however, for evidently it was taken from *Astragalus hamosus* L., a European species, which is an annual and has an almost terete and thick-walled pod, and belongs to a group not represented in America. Jones' section is also unnatural, comprising species of widely different affinities, as *A. distortus* and *A. Engelmanni* without any septum (Jones' illustration of the cross-section of the pod of the former is faulty); *A. glaber*, related to *A. Leibergii; A. Orcuttianus, A. Howellii, A. misellus, A. Nevisii*, and *A. Traskiae*, which constitute a group related to what Jones called *Galigiformes;* and *A. Mulfordi*, whose nearest American relative is *A. Bolanderi.*

The group is characterized by the perennial root, crowned by a cespitose, more or less woody caudex, leafy stems, comparatively short calyx-tube, usually middle-sized corollas (8–15 mm. long), linear or narrowly oblong pod, which is glabrous or striate, more or less arcuate, sessile (or if stipitate, articulate to the minute stipe, which therefore is a prolongation of the receptacle, not of the pod), more or less compressed, cordate in cross-section, sulcate but not deeply so on the lower suture, and with a complete or nearly complete septum.

Calyx more or less black-hairy.
Pod glabrous.
Stem and leaves glabrous or nearly so........ 9. *H. umbratica*
Stem and leaves pubescent.
Pubescence appressed; leaflets oblong.
Stem slender; leaflets strigose on both sides; corolla about 8 mm. long......................... 10. *H. bernadina*

Stem stout; leaflets white silvery above; corolla 15–16 cm. long..... 11. *H. tricarinata*
Pubescence spreading, leaflets obovate, retuse......................... 12. *H. Greggii*
Pod strigose; plant distinctly pubescent.
Leaves and stem villous; pod acuminate, 15–16 mm. long.
Corolla white or pale; pod reflexed-spreading; stems tall erect........... 13. *H. Congdoni*
Corolla dark purple; pod erect; stem low, decumbent.................... 14. *H. Gooddingii*
Leaves strigose beneath, glabrate above.
Stem 1–2 dm. high; stipules large, broadly ovate, scarious; pod firm..... 15. *H. ensiformis*
Stem 3–5 dm. high; stipules small, subulate to deltoid; pod thin walled.
Corolla 8–10 mm. long, purple veined; leaflets obovate, scarcely notched...................... 16. *H. drepanoloba*
Corolla 7–8 mm. long, white; leaflets ovate or oval, deeply notched. 17. *H. Paysonii*
Calyx white-hairy.
Leaves silky-canescent on both sides, keel not acuminate.
Leaflets 7–11, oval-obovate, rounded at the apex; corolla purple.................... 18. *H. albens*
Leaflets 9–19, linear or oblong, acute or obtuse; corolla white or nearly margined with purple.
Leaflets 9–15, linear, more than 1 cm. long............................ 19. *H. arizonica*
Leaflets 15–19, oblong, 5–8 mm. long.... 20. *H. Coahuilae*
Leaflets glabrate above; keel acuminate......... 39. *H. nothoxys*

9. **Hamosa umbratica** (Sheldon) Rydb. *Astragalus sylvaticus* S. Wats. Proc. Am. Acad. **23**: 262. 1888. Not *A. sylvaticus* Willd. *Astragalus umbraticus* Sheld. Minn. Bot. Stud. **1**: 23. 1894. This is characterized by being glabrous even as to its pod.

OREGON: Glendale, *Howell 674*, in 1887; *Henderson 1342;* Muriel, *J. C. Nelson 1393;* Josephine County, *Peck*, in 1918.—CALIFORNIA: Humboldt County, *Mrs. Manning 181; Rattan*, in 1883; *Joseph P. Tracy 4598, 4575*.

10. **Hamosa bernadina** (M. E. Jones) Rydb. *Astragalus bernadinus* M. E. Jones, Proc. Calif. Acad. II. **5**: 661. 1895. This species is related to *H. Congdoni* and *H. arizonica*, but

differs from both in the glabrous pod, from the former in the strigose pubescence, and from the latter in the broader leaflets and the black-hairy calyx. It differs from *H. tricarinata* in the slender habit, much smaller flowers, and the leaflets not being silvery beneath.

CALIFORNIA: San Bernadino Mountains; *Parish 2581;* Jucumba, *Eggleston 19724;* Coronado Forest *19821*, *19836;* Ashberry Range, Sta. Cruz County, *19840*.

11. **Hamosa tricarinata** (A. Gray) Rydb. *Astragalus tricarinatus* A. Gray, Proc. Am. Acad. **12:** 56. 1876. This is characterized by the stout habit, large flowers, and leaves silvery beneath.

CALIFORNIA: 'Southern California,' *Parry & Lemmon 88;* White Water, *Parry 2;* San Bernadino, *Parish 92;* Coyote Cañon, *H. M. Hall 2858;* Jucumba; *Eggleston 19724.*

12. **Hamosa Greggii** (S. Wats.) Rydb. *Astragalus Greggii* S. Wats. Proc. Am. Acad. **17:** 343. 1882. This is not closely related to any of the other species of the group, as the pubescence is spreading and the leaflets are broad and retuse at the apex. Jones placed the species in his Micranthi, but at the same time compared it with *Astragalus Lindheimeri* and *A. Nuttallianus.* The pod however, places the plant in the TRICARINATAE.

COAHUILA: Saltillo, *Palmer 258*, in 1880.

13. **Hamosa Congdoni** (S. Wats.) Rydb. *Astragalus Congdoni* S. Wats. Proc. Am. Acad. **20:** 360. 1885. This species differs from the other species of the group in its villous pubescence, long and lax racemes, large white flowers, and rather narrow calyx-tube.

CALIFORNIA: Mariposa County, *Congdon* in 1883, 1892, and 1893.

14. **Hamosa Gooddingii** Rydb. sp. nov. Perennial, with a cespitose caudex; stems decumbent, about 1 dm. high, strigose; leaves spreading, 2–3 cm. long; stipules ovate, 2–3 mm. long; leaflets 9–13, obovate to elliptic, rounded or obtuse at the apex, 3–5 mm. long, 2–3 mm. wide, glabrous above, strigose beneath; peduncles 7–10 cm. long, strigose, arcuate; raceme 2–4 cm. long; bracts 2 mm. long, lanceolate; calyx strigose with mixed black and white hairs, the tube 4 mm. long, the teeth subulate, 2 mm. long; corolla dark, bluish-purple, about 1 cm. long; banner obovate, retuse; wings shorter, the blades oblong-falcate, with a broad basal auricle; keel-petals much shorter, the blade

broadly lunate, strongly arched, rounded at the apex; pod lance-linear, 1.5–2 cm. long, 3 mm. high and broad, somewhat falcate, minutely strigose or in age glabrate, deeply cordate in cross section, membranous.

Type collected on rocky slope in the Huachuca Mountains, Arizona, May, 1912, *Gooding 1299* (herb. N. Y. Bot. Gard.).

15. **Hamosa ensiformis** (M. E. Jones) Rydberg. *Astragalus ensiformis* M. E. Jones, Proc. Calif. Acad. II. **5**: 658. 1895. Though I have placed this species next to *H. drepanoloba* and *H. Paysonii*, it is not closely related to either, differing in the firm pod and leaves, the low habit and the large scarious stipules. The corolla is unknown. Jones first described it under *Astragalus ursinus*, stating that the 'flowers seem to be identical with those of *arietinus*, but paler.' The type sheet, now at Pomona College, has no flowers. It is known only from the type collection from Pagumpa, Ariz., *Jones 5095ah*.

16. **Hamosa drepanoloba** (A. Gray) Rydb. *Astragalus drepanolobus* A. Gray, Proc. Am. Acad. **19**: 75. 1883. This resembles much *H. umbratica* in leaf-form and somewhat in general habit, but the stems are decumbent and strigose, the leaflets are glabrous above, strigose beneath and the pod is almost papery and finely strigose. The corolla is evidently pale-purple when fresh, with the banner decidedly purple-veined, but soon fades and becomes almost white.

Hooker in his Flora Boreali Americana described a species *Astragalus diaphanus* from specimens collected by Douglas at the Great Falls of Columbia. This was unknown to Gray when he wrote his revision but he stated: 'I learn that the plant has the aspect of *A. distortus*,' which is the case with *H. drepanoloba*. It was also unknown to Watson, but in his Bibliographical Index, he made it a synonym of *Astragalus lentiginosus* Dougl. Sheldon simply admitted it as a species without any remarks. Piper made it a questionable synonym, and it is indeed very questionable if referred to *A. lentiginosus*. Jones (Proc. Calif. Acad. II. **5**: 675. 1895) made it a variety of *A. lentiginosus*, apparently without ever having seen any specimens agreeing with Hooker's description. There is nothing in that description except the number of leaflets (5–9 pairs in Hooker's description, and usually 4–5, rarely 6 pairs in *H. drepanoloba* as far as known), which does not fully agree with *H. drepanoloba*. I suspect that *A. diaphanus* is the oldest name for this species. Stretch's specimen is less pubescent, more slender and low-stemmed, but cannot be separated specifically. Jones determined this as *A. iodanthus*, to which it evidently does not belong.

WASHINGTON: Bingen, *Suksdorf 7726*.—OREGON: John Day River, *Howell*, in 1882 and 1885.—NEVADA: Washoe Valley, *Stretch 265*.

17. **Hamosa Paysonii** Rydb. sp. nov. Perennial, with a woody caudex; stems many about 5 dm. high, glabrous or nearly so, striate, light-green; leaves ascending, 7–10 cm. long; stipules deltoid, 3–4 mm. long; leaflets ovate or oval, deeply notched at the apex, 10–17 mm. long, 4–10 mm. wide, glabrous above, strigose beneath; peduncles 5–10 cm. long, erect, racemes 4–5 cm. long; bracts lance-subulate, 2 mm. long or less; calyx black-hairy, the tube 2.5–3 mm. long, the teeth subulate, 2 mm. long; corolla white, 6–8 mm. long; banner obovate, rather abruptly arched; wings shorter, the blade rather broad, elliptic; keel-petals shorter, broadly lunate, rounded at the end; pod (immature) oblong, tapering at each end, 2 cm. long, 3 mm. broad and thick, strigose, the cross-section somewhat obcordate.

Type collected at Horse Creek, seven miles west of Merna, Sublette County, Wyoming, *Payson & Payson 2748* (herb. N. Y. Bot. Gard.).

18. **Hamosa albens** (Greene) Rydb. *Astragalus albens* Greene, Bull. Calif. Acad. **1**: 156. 1885. This is related to *H. arizonica*, but differs in the more slender decumbent stems, the smaller flowers, shorter peduncles, and broader leaves. Jones (Rev. Astrag. 261. 1923) described the pod as 'arched mostly to a circle, . . . when mature coriaceous, strongly corrugated, 2–3 cm. long, 3 mm. wide and high, flat for about 1 mm. high along the ventral suture and forming a thick wing, etc.' In the type number the pod is only 1.5 cm. long, forming an arch of about one fourth of a circle, neither coriaceous nor corrugated. The rest of the description is unintelligible to me

CALIFORNIA: Mojave Desert, *Parish 1274;* Colorado Desert, *Eastwood 2690*.

19. **Hamosa arizonica** (A. Gray) Rydb. *Astragalus arizonicus* A. Gray, Proc. Am. Acad. **7**: 398. 1868. This is characterized by the narrow, usually linear, white-strigose leaflets.

ARIZONA: *Palmer 591, 100*, in 1876; Bishop Creek; *Mearns 350;* Camp Grant, *Palmer 53*, in 1867; Skull Valley, *Jones*, in

1903; Calabasas, *Tidestrom 865;* Tucson, *Griffiths 3542;* Mescal Mountains, *Jones*, in 1890; Oracle, *Griffiths 3730; Patagonia, Tidestrom 818;* Santa Rita Forest, *Griffiths 3804;* Skull Valley, in 1903; Little Colorado, *Ward*, in 1901; Apache, *Eggleston 19851;* Crook Forest, *19898;* Fort Grant, *19932;* Klondyke, *19938.*—SONORA: Tubac, *Parry* in *Mexican Boundary Survey 267;* Los Nogales, *E. K. Smith.*—NEW MEXICO: Aztec, *Baker 417;* Fort Wingate, *Matthews*.

20. **Hamosa Coahuilae** (M. E. Jones) Rydb. *Astragalus Coahuilae* M. E. Jones, Rev. Astrag. 256. 1923. This is related to the preceding, but is erect, much branched, grayish canescent with short kinked hairs, the pods are smaller and strongly ascending. Jones in his key compares it with *Astragalus glaber*, to which it has no close relationship. Earlier he had determined Palmer's specimens as *A. nothoxys*, to which it is closely related, but the pubescence is different and the keel not beaked.

COAHUILA: Parras, *Palmer 234; Purpus 4672.*

Four new Melastomataceae from Peru

H. A. GLEASON

Among the collections of Dr. Francis W. Pennell, made in Peru, Bolivia, and Chile in 1925, the following undescribed species appear. While the types are in each case in the herbarium of the New York Botanical Garden, duplicates of the same collection numbers are in the Gray Herbarium of Harvard University, the herbarium of the Field Museum of Natural History, and the herbarium of the Academy of Natural Sciences of Philadelphia. The duplicates have not been examined by the author.

Brachyotum nutans n. sp. Stems shrubby, the bark exfoliating on the older parts; young twigs sparsely appressed-setose and with a ring of erect setae at each node, becoming glabrous with age; petioles 2–3 mm. long, usually with 2 or 3 appressed setae; leaf-blades ovate-oblong, thick, dark green above, yellowish-green beneath, 8–12 mm. long, 4–6 mm. wide, rounded at base and apex, conspicuously setose-ciliate on the recurved margins, glabrous and somewhat rugose above, glabrous on the surface, sparsely appressed-setose on the veins, and prominently dark-punctate beneath; principal veins 3, somewhat saccately confluent at base, veinlets obsolete; floriferous branchés from the upper axils, about 1 cm. long, erect, bearing a single pair of reduced leaves and a nodding terminal peduncle 5 mm. long; flowers 4-merous; hypanthium broadly campanulate, 4–4.5 mm. long to the staminal torus, 4.5 mm. in diameter, glabrous or sparsely appressed-setose; calyx-limb prolonged 1 mm. beyond the torus, the sepalar sinuses paraboloid, entire, 1 mm. deep and wide, with an erect basal seta; sepals triangular, 4.7 mm. long, 4.3 mm. wide, acute, setose-ciliate, somewhat carinate; corolla royal purple, the petals 19 mm. long, finely ciliate, reticulately veined, the exposed side semi-ovate, 7 mm. wide, the concealed side semi-rhomboid, 8 mm. wide, with an obtuse lateral lobe; filaments stout, somewhat flattened, 3.5 mm. long, 0.8 mm. wide; anthers nearly straight, lance-elliptic, blunt, 3.5 mm. long, 1.2 mm. wide, the connective with a minute dorsal protuberance at base and two anterior callosities 0.3 mm. long; ovary 4-celled, ellipsoid, 4.7 mm. long, somewhat 4-lobed, the terminal lobes broadly deltoid, blunt, 0.5 mm. long, pilose with straight erect hairs; style slender, straight, 26 mm. long; stigma slightly clavate, blunt, 0.5 mm. in diameter, minutely pilose.

Type, *Pennell 13,847*, collected on open grassy paramo, Paso de Tres Cruces, Cerro de Cusilluyoc, Dept. Cuzco, Peru, 3 May

1925, and deposited in the herbarium of the New York Botanical Garden. *Brachyotum nutans* belongs to the 4-merous group of the section *Adesmiae*, in which only five species have been hitherto described. Of these, only *B. alpinum* Cogn. has leaves glabrous above. It differs from ours in the densely pilose twigs, nodes, petioles, lower leaf-surface, and hypanthium, in the leaves acute at base and with developed veinlets, in the relatively shorter and more pilose sepals, and in the much shorter petals. The heavy development of pubescence on *B. alpinum* gives it quite a different general aspect.

Cogniaux erected the section *Octomeris* of the genus *Tibouchina* to include the single species *T. octopetala* Cogn., based on a collection by Rusby in Bolivia, the type of which is conserved in the herbarium of Columbia College at the New York Botanical Garden. A recent collection by Pennell, numbered *14,039*, now extends its range into Peru. It agrees in every essential respect with the type, differing only in minor details of the pubescence. Another collection by Pennell, numbered *13,971*, from the same general locality and altitude, represents a new 8-merous species and differs notably in several important features.

Tibouchina pulcherrima n. sp. Stems shrubby, the upper branches obscurely quadrangular, densely clothed with an indument of short, curved, red-purple, flexuous hairs, the larger internodes 10–15 cm. long; petioles stout, 20–25 mm. long, densely short-hirsute with red-purple hairs; leaf-blades firm, narrowly ovate-oblong, 15–18 cm. long, 6–7.5 cm. wide, long-acuminate, obtuse at base, setose-ciliate, 5-nerved, with an additional pair of faint marginal nerves, upper surface velvety green, densely covered with short, stout, conic tubercles, somewhat thickened at the obscure angles and terminated by a short, ascending, subulate seta, lower surface cinereous, each areole deeply foveolate, the veinlets marked by straight, whitish, spreading hairs 0.5 mm. long, first and fifth veins arising from the second and fourth 1–2 cm. above the base, the principal veins and secondaries marked by dense pubescence of purple-red, ascending, subulate, minutely plumose hairs nearly 2 mm. long; inflorescence terminal, few-flowered, the peduncles 5 cm., the pedicels 10–15 mm. long; bracts obovate, 10 mm. long, 8 mm. wide, broadly rounded at summit, setose-ciliate, densely hirsute on the back; flowers 8-merous; hypanthium broadly subcylindric, 7 mm. long to the staminal torus, 16-nerved on the inside, densely hirsute with purple curved-ascending setae nearly 2 mm. long; calyx-limb 1.6 mm. long; sepals oblong, 6 mm. long, 2 mm. wide, narrowed from the middle to an acute tip, many-nerved, setose-ciliate, densely purple-hirsute on the back; petals cuneate-obovate, 13 mm. long, 10 mm. wide, broadly truncate, finely ciliate; filaments somewhat flattened at base, glabrous, 6.5–7 or 7.5–8 mm. long; anthers linear-subulate, glabrous, 5.5–6 or 7.5–8 mm. long, opening by a single terminal pore; connective of the short stamens scarcely prolonged, appendaged anteriorly by 2 obliquely ovoid, nearly erect processes 1 mm. long and minutely gibbous dorsally; connective of the long stamens prolonged 1–1.5 mm. at right angles to the anther, its appendages nearly erect, 1.3 mm. long; ovary free, 4-celled, short-ovoid, 8 mm. long, erect-setose on the distal fourth, prolonged at the summit into 8 blunt ovoid lobes 0.7 mm. long; style stout, terete, 10 mm. long, conspicuously hirsute below; stigma capitate, barely expanded, 1.2 mm. in diameter.

Type, *Pennell 13,971*, collected in forest, 'Pillahuata,' Cerro de Cusilluyoc, Dept. Cuzco, Peru, alt. 2200–2400 m., 3–6 May 1925, and deposited in the herbarium of the New York Botanical Garden. *T. pulcherrima* differs from *T. octopetala* Cogn. in its conspicuously purple, shorter indument, in its much longer and proportionately narrower leaves, in its beautifully purpled veins and conspicuous secondaries, in details of its leaf-pubescence, in its long peduncles and pedicels, producing an open inflorescence, in its shorter filaments, and its erect basal lobes of the connectives.

Tibouchina dimorphylla n. sp. Fruticose; upper branches sharply 4-angled with channeled sides, thinly pubescent with short, spreading, more or less flexuous hairs, the larger internodes 16 cm. long; principal leaves on petioles 3–4 cm. long and densely pubescent, the blades ovate-oblong, acute, minutely denticulate with setiferous teeth, rounded at base, 18 cm. long, 7 cm. wide, 5-nerved, the upper surface bullate and sparsely hirsute with subappressed subulate setae 1 mm. long, the lower surface foveolate, thinly pubescent on the veinlets with short white hairs 0.2–0.4 mm. long, and more densely pubescent on the nerves with stout hairs 0.4–0.8 mm. long, outer nerves arising from the intermediates 2–5 mm. above the base; leaves subtending the floriferous branches with petioles 8–15 mm. long, the blades cordate-ovate, 6.5–10 cm. long, acute or subacuminate, distinctly cordate at base, irregularly 5–7-nerved, the lamina arising at the junction of the outer and intermediate nerves; uppermost leaves 3–4 cm. long; inflorescence compact, few-flowered, on densely pubescent peduncles 3–5 cm. long; pedicels 3–12 mm. long; flowers 5-merous; hypanthium subglobose, 5 mm. high, densely hispid with curved-ascending, subulate hairs 1 mm. long, obscurely 10-nerved, calyx prolonged 0.6 mm. beyond the staminal torus, its sinuses broadly rotund; sepals 5 mm. long, triangular-deltoid at base, the free tip linear, obtuse, hispid like the hypanthium; petals ovate, violet, 10–12 mm. long, finely ciliate at base and apex, tipped with a seta 1 mm. long; filaments essentially terete, 5.2 or 5.9–6.3 mm. long, glabrous; anthers subulate, 4 or 4.8–5 mm. long; connective bent introrsely and prolonged about 1 mm. in the larger stamens, minutely gibbous on the back, extended anteriorly into 2 truncate appendages 0.5 mm. long and 1 mm. wide; ovary free, subhemispheric, 4 mm. high, hispid on the upper two-thirds, obscurely 5-lobed, each lobe tipped with a fleshy, glabrous, truncate protuberance 0.5 mm. long and 1 mm. wide; style stout, terete, 10 mm. long; stigma capitate, scarcely expanded.

Type, *Pennell 14,109*, collected in a thicket in a valley on the paramo above 'Pillahuata,' Cerro de Cusilluyoc, Dept. Cuzco, Peru, alt. 3000–3300 m., 3–6 May 1925, and deposited in the herbarium of the New York Botanical Garden. It is a member of the group numbered 120–122 in Cogniaux' Monograph, including *T. Rusbyi* Cogn., *T. mollis* (Bonpl.) Cogn., *T. Solmsii* Cogn., *T. adenophora* Cogn., *T. cymosa* Cogn., and *T. rhynchantherifolia* Cogn. Of these, it is most closely similar to the well known *T. mollis*, from which it differs in its larger leaves on longer petioles, conspicuously thinner leaf-pubescence, longer peduncles and pedicels, small and few-flowered inflorescence, and sparser pubescence on the hypanthium.

In *Pennell 14,092*, collected at the same locality, the inflorescence is larger, the upper cordate leaves are smaller, the internodes are shorter, and the hypanthium and sepals are smaller. It seems to agree with the type in every respect except dimensions, and I tentatively refer it to the same species.

Axinaea Pennellii n. sp. Arborescent, leaf-buds and undeveloped internodes densely ochraceous-furfuraceous with branched hairs, the older parts soon becoming glabrous; younger twigs irregularly and obtusely 4-angled, the older subterete; nodes conspicuously tumid and marked with an annular scar; petioles thinly furfuraceous, 18–22 mm. long; leaf-blades firm, dark dull green above, yellow-green beneath, ovate-oblong, 10–16 cm. long, 3.5–6 cm. wide, the members of each pair slightly unequal, long-acuminate to a narrow but blunt, rounded tip, conspicuously denticulate with low (about 1 mm.), remote (about 5 mm. apart), blunt teeth, cordate at base, the basal lobes and 5–10 mm. of the margin reflexed and overlapping on the lower side and connate on the upper side into a small tubercle, glabrous and inconspicuously reticulate above, thinly furfuraceous on the surface, more densely so along the veins, and obscurely reticulate beneath; principal nerves 5, with an additional pair of weak marginal nerves; secondary nerves arising at an angle of about 80°, 2–3 mm. apart; inflorescence terminal, about 10-flowered; pedicels sparsely furfuraceous, 5–10 mm. long; flowers 5-merous; hypanthium (including the limb) broadly hemispheric 5 mm. high, 8 mm. broad, glabrous or rarely a trifle furfuraceous, the limb entire, prolonged 2 mm. beyond the staminal torus; petals purple, fleshy, broadly oblong-elliptic, 20 mm. long by 12 mm. wide, obtuse or rounded, glabrous; stamens slightly unequal; filaments stout, fleshy, flattened, 8 or 10 mm. long, 2 mm. wide, glabrous; anthers stoutly subulate, 6 or 8 mm. long, minutely 1-pored; connective inflated posteriorly, ovoid, 5–6 mm. long by 3–4 mm. in diameter; ovary 4 mm. high, obscurely 5-ridged, prolonged at summit into 5 short obtuse lobes; style terete, slightly tapering, somewhat bent, 14 mm. long; stigma minute, truncate.

Type, *Pennell 14,003*, collected on a forested cliff above Rio Pillahuata, Dept. Cuzco, Peru, 3–6 May 1925, and deposited in the herbarium of the New York Botanical Garden. It differs from the other members of the group, seven in number, in its larger and proportionately narrower leaves, much larger flowers, the thinly furfuraceous indument, and the conspicuously reflexed basal lobes of the leaves. Its nearest relative is *A. Weberbaueri* Cogn.

Notes on Mielichhoferia

EDWIN B. BARTRAM

(WITH TWENTY TEXT FIGURES)

Prof. A. O. Garrett and his Boy Scout associates from Salt Lake City were engaged in the laudable effort of broadening our knowledge of the moss flora of Utah by field work in the vicinity of their summer camp in the Wasatch Mountains, Utah County, during July and August of 1925. A portion of their collections was transmitted to the writer for determination through the courtesy of Mr. A. T. Beals and in this lot occurs a gathering representing a new variety of *M. macrocarpa* which has led to some suggestive comparisons that are briefly summarized below.

The genus *Mielichhoferia* is richly represented in the cordillera of South America, more sparingly in Mexico, while in the United States and Canada only two species have been recorded, both of them rare and practically confined to the Rocky Mountain region. These two species, *M. macrocarpa* (Hooker) Bruch & Schimper and *M. cuspidifera* Kindberg, are clearly separable from the European group, comprising *M. nitida* Hornschuch and *M. compacta* (Hoppe & Hornsch.) Kindberg, in the usually percurrent or even excurrent costa, the nearly entire leaf margins, and especially in the relatively thin walled, lax leaf cells, which contrast strongly with the yellowish incrassate, linear areolation of the European plants. An examination of part of the type material of *M. cuspidifera* Kindberg confirms the distinctions given in the original brief description.[1] The broadly ovate, abruptly pointed, concave leaves and the relatively broader and shorter leaf cells give the plant a very characteristic appearance under the microscope, as may be noted in the text-figures 16 to 20. Although known only from the type locality and in sterile condition the plant can hardly be considered otherwise than as a distinct species.

M. macrocarpa has been characterized by the more obtuse leaves and innovations more clavate and densely foliate in relation to *M. nitida*, to which it was at one time appended as a variety.[2] In Drummond's Musci Americani no. 74, upon

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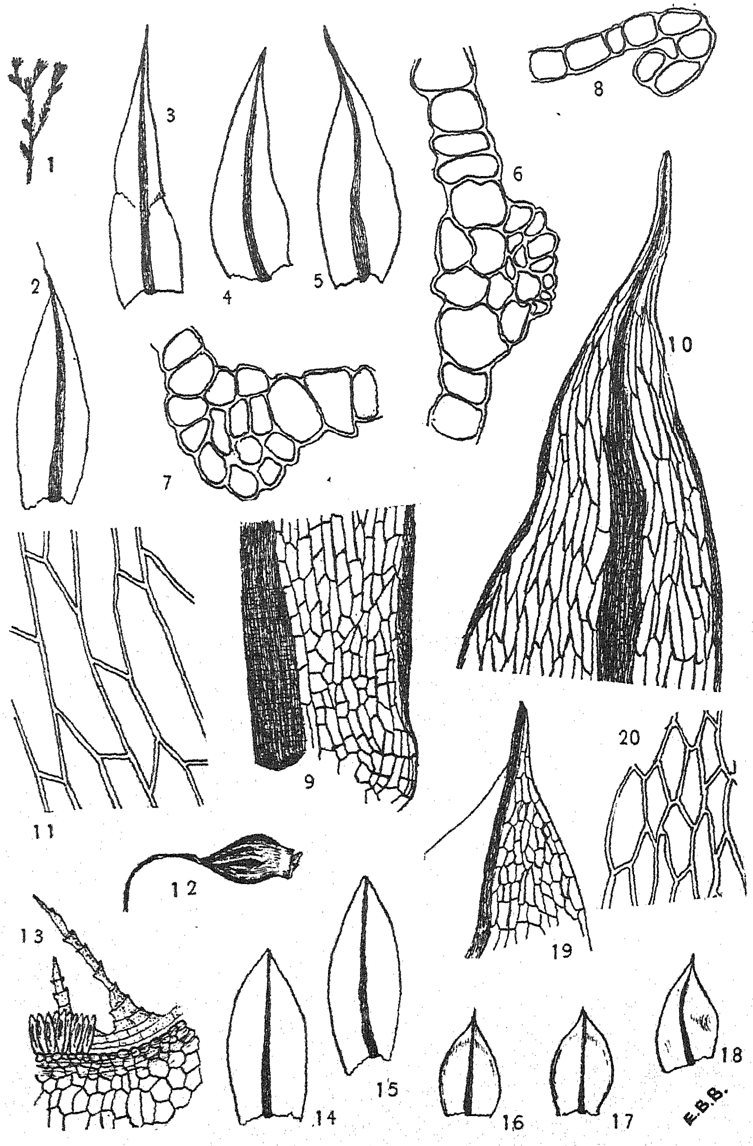
[1] Macoun & Kindberg. Catalogue of Canadian plants, part 6: 110. 1892.

[2] Carl Müller. Syn. Musc. Frond. **1**: 235. 1849.



FIGS. 1–13. MIELICHHOFERIA MACROCARPA PUNGENS Bartram. FIG. 1. Male plant × 1. FIGS. 2–5. Leaves × 20. FIG. 6. Cross section from lower half of costa × 300. FIG. 7. Cross section from upper half of costa × 300. FIG. 8. Cross section of leaf margin × 300. FIG. 9. One side of leaf base × 100. FIG. 10. Apex of leaf × 100. FIG. 11. Median leaf cells × 300. FIG. 12. Dry, partially deoperculate capsule × 8. FIG. 13. Two peristome teeth × 100.

which this species was based, the flaccid, loosely spreading upper and comal leaves, broadly concave, essentially entire in the acumen and usually costate to the apex, bear little resemblance to the firm, narrowly lanceolate, erect and imbricated leaves of the European species. Specimens from Barclay Island, collected by Dr. Lyall in 1854, agree with the North American forms in the essential characters, and although one tuft is slender with obtusely pointed leaves, and the other short and stunted with more acute leaves, they probably represent variants of *M. macrocarpa* influenced by environmental factors. References to the occurrence of *M. nitida elongata* on Mt. Ktaadn, Maine, in Rhodora **3**: 180, 182, and in the Bryologist **22**: 75, are apparently based on a misconception of the plants collected by Dr. G. G. Kennedy (*no. 2243*) on July 11, 1900, which seem to represent an aberrant form of *Philonotis* sp. A collection from the White Mountains, New Hampshire by C. F. Austin in September, 1872 is the only available record east of the Rocky Mountains, and may be clearly referred to *M. macrocarpa.*

The collections from Utah show a well marked variant of *M. macrocarpa*, which may be designated as *Mielichhoferia macrocarpa* (Hooker) Bruch & Schimper, var. **pungens** var. nov.; it differs from the typical form in the leaves narrowly acuminate, frequently sharply cuspidate, and the leaf margins narrowly recurved from the base nearly to the acumen. Plants densely tufted, about 15 mm. high, yellowish green at the tips, brown and radiculose below, stems slender and brittle, fastigiately branched; leaves erect spreading, rather loosely imbricated and more or less flexuous when dry, ovate lanceolate, gradually tapering to a sharp point, margins narrowly recurved from just above the base nearly to the acumen, essentially entire; costa rather strong, about 50 μ wide at the base, tapering upward, more or less flexuous, percurrent or excurrent into a smooth cuspidate point, in cross section near the base showing several rather poorly differentiated median guide cells with a ventral layer of similar form and a dorsal band of two layers of smaller, thicker walled cells, in the upper half nearly homogenous in

FIGS. 14, 15. MIELICHHOFERIA MACROCARPA (Hooker) Bruch & Schimper. Two leaves from Drummond's Musc. Amer. no. 74.

FIGS. 16–20. MIELICHHOFERIA CUSPIDIFERA Kindberg. FIGS. 16–18. Three leaves × 20. FIG. 19. Apex of leaf × 100. FIG. 20. Median leaf cells × 300 about four layers, but with the cell walls more incrassate on the dorsal side; leaf cells thin walled and almost hyaline, especially in the older leaves, linear-rhomboidal, up to 80 μ long by 13 μ wide, narrower toward the margins, shorter and subrectangular at the base, a few at the extreme angles quadrate and somewhat swollen; seta flexuose, 4 to 5 mm. long, pallid green becoming brown at maturity, neck short and sulcate; operculum flat or very slightly convex and minutely mammillate; peristome single, of 16 pale, linear teeth, widened and confluent at the base, from a short basal membrane; annulus compound, large and persistent; spores about 15 μ in diameter, granulose. Dioicous, male flowers gemmiform and lateral on the stem and branches, antheridia 6 to 8, about 225 μ long with few paraphyses, perigonal bracts numerous, the inner shorter, blunt and loosely areolate. UTAH: Wasatch Mts., Utah Co., cave, near snow above Second Falls, July 29, 1925, *A. O. Garrett 163* (type); dripping limestone cliffs south of First Falls, August 11, 1925, *S. F. Flowers 330;* dripping limestone cliffs by large cave, August 19, 1925, *M. Harris 443;* dry cliffs by large cave, August 18, 1925, *M. Harris 444* and *460.* COLORADO: west of Ouray, canyons and meadows, alt. 2300 to 2800 m., September 9, 1901, *L. M. Underwood and A. D. Selby.*

I wish to express my sincere thanks to Mrs. N. L. Britton for the type material of *M. macrocarpa* and for the specimens from Colorado and Barclay Island; to Dr. Hjalmar Möller of the Naturhistoriska Riksmuseum, Stockholm, Sweden, for the type material of *M. cuspidifera;* and to Prof. J. F. Collins for the specimens from Maine and New Hampshire. The European plants used for comparison are represented by Dr. Bauer's Musci Europaei Exsiccati nos. 901 and 902 from the classic locality near Salzburg.

BUSHKILL, PENNSYLVANIA

Adventitious roots and shoots in an introduced weed

C. L. Wilson

(WITH TWO TEXT FIGURES)

Roripa austriaca Spach, of the family Cruciferae, is a perennial weed recently introduced from Europe. So far, the plant is limited in its distribution. It has been found at Madison, Wisconsin, and within a limited area in Orange County in southern New York, extending across the state line into New Jersey. The writer is indebted to Professor W. C. Muenscher, of Cornell University, for material for the study of vegetative reproduction in this plant, and for information concerning the distribution of the weed.

The term, adventitious, as applied to structures of the plant body, refers in general to any organ produced in an abnormal position on the plant. Roots produced from leaves, roots from stems, and shoots from roots, as well as emergences of various kinds, such as the haustoria of *Cuscuta*, are classified as adventitious structures. Such structures occurring in *Roripa* consist of roots produced on the stem in the axils of branch buds, and of shoots produced upon roots. Adventitious roots are of course produced only upon subterranean stems, or upon aërial stems when these come in contact with soil, as in cultivation. Several roots are ordinarily produced in an axil, three being the usual number. Shoots may be produced almost anywhere upon roots, young or old, especially if these run near the surface of the soil.

According to Van Tieghem (1), adventitious shoots produced upon roots are endogenous in their origin. The term endogenous, in this connection, refers to a method of growth by which a structure in the early stages of development is covered by a layer of tissue of the producing member which does not appear in the formation of the new structure. The production of secondary roots is an example of this. In the production of an adventitious shoot, a number of cells of the pericycle elongate and divide, forming an arc (as seen in section view) of meristematic tissue. By apical growth this tissue pushes its way through the cortex and epidermis.

The writer has found that *Roripa* produces adventitious shoots on roots in a manner which constitutes an exception to this condition. In this plant, adventitious shoots on roots are exogenous. The growing point of the new shoot is formed as a result of a large number of divisions of cells close to the periphery of the root. In very young roots, this growing point would result from the division of both cortical and epidermal cells. In the root of *Roripa*, however, cork forms at a very early stage. After the formation of cork, the growing point must develop from the continued division of cortical cells just under the cork, resulting in the sloughing off of the cork in front of the protuberance thus formed.

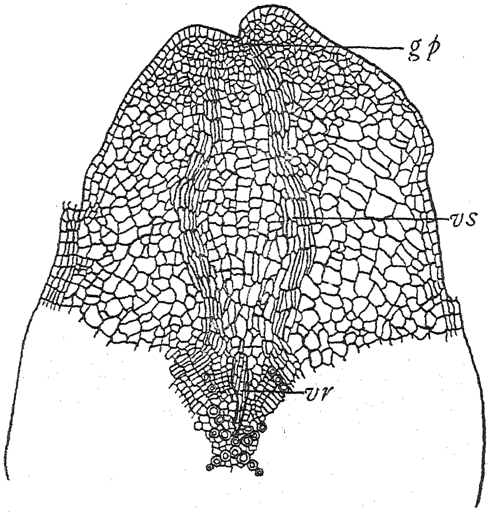


FIG. 1. Cross section of root, showing origin of exogenous shoot. *gp*, growing point of new shoot. *vs*, vascular supply to new shoot. *vr*, portion of vascular supply to a secondary root which is found close to the adventitious shoot. The remainder of the vascular supply to this root is out of the plane of the drawing.

At the same time that the formation of the growing point is going on, a number of cells of the cortex elongate and divide radially. This process extends from the pericycle to the growing point. The tissue takes the form of a cylinder, and constitutes the vascular system of the new shoot. An adventitious shoot of this type usually develops in connection with a secondary root, which appears externally at the side or in the axil of the new shoot. This secondary root may divide several times near the periphery of the root, and appear externally as two or three roots. Figure 1 represents a cross section through a root at the region of formation of an adventitious shoot.

Van Tieghem and Duliot (2) have described the origin of adventitious shoots on roots in *Alliaria officinalis* (Cruciferae). According to these writers, adventitious shoots in this plant are produced endogenously, by the formation of an arc of meristematic tissue from the cells of the pericycle. If the observations of these writers are correct, the condition just described for *Roripa* is not true for all of the Cruciferae. However, such a condition is not entirely exceptional in plants. Van Tieghem (1), in working upon various species of *Linaria*, confirmed the conclusions of previous workers, that the root shoots in this genus are exogenous. The description of the origin of adventitious shoots in *Linaria* sp. accords in all essential details with the description of the same condition in *Roripa*. It is very probable that upon further examination other plants in addition to those just discussed will be found to have adventitious shoots originating in an exogenous manner.

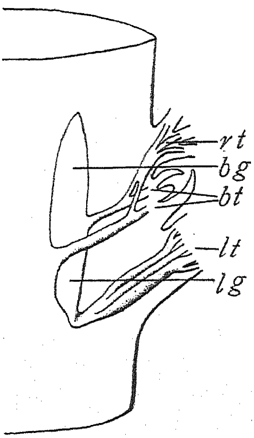


FIG. 2. Nodal anatomy of the stem in a region in which adventitious roots have developed. *rt*, vascular supply to adventitious roots. *bg*, branch gap. *bt*, branch traces. *lt*, leaf traces. *lg*, leaf gap.

Adventitious roots on stems are ordinarily produced in the same manner as secondary roots; that is, endogenously. Roots produced in the axils of branch buds in the Cruciferae are, however, an exception to this general condition. Epidermal and cortical cells in the axil of a normal branch bud divide until a protuberance is formed, the beginning of the new root. While this is going on, cells of the cortex, in a region extending from the branch traces to the growing point of the root, elongate and divide, and form the vascular tissue of the root. The epidermis of the root and stem are continuous, and the root is therefore exogenous. Lemaire (3) discusses this in some detail, although he was not the first to observe this condition. Figure 2 represents a diagrammatic view of the vascular connections of leaf, branch, and adventitious roots as seen in a node of *Roripa*. The leaf traces are five in number. The gap formed by the passing off of the leaf traces merges with the branch gap. As the two branch traces approach the periphery of the stem, each gives rise to a strand of vascular tissue, just before fusing to form the vascular cylinder of the branch. These strands may quickly unite, and divide again into three parts, each constituting the vascular supply to a rootlet. This is the condition shown in figure 2. There may be variations from this condition. Frequently the branch traces give rise to strands which pass out of the stem without fusing. In such a case, if three rootlets are formed in the axil, the vascular supply of the central one is provided by a branch coming from the vascular supply of one of the lateral roots.

Van Tieghem and Duliot (2) likewise found that endogenous roots are produced by the Cruciferae on the hypocotyledonous stem. The writer has not observed such structures in *Roripa*. Many adventitious roots are found on this portion of the stem, but very probably all are exogenous roots produced in connection with aborted leaf and branch buds. There is no reason to suppose, however, that such roots may not develop.

In conclusion, emphasis may be laid upon the fact that in the root, endogenous and exogenous structures are developed in close connection with each other. Shoots are formed having a different origin from those of the other appendages of the root, but having the same origin as the branch and leaf. On the stem, on the other hand, are developed roots which have the same origin as the branch and leaf. The ability of the roots and shoots of *Roripa austriaca* to develop these adventitious structures so freely, even under adverse conditions, makes it a very serious weed pest. It is thereby enabled not only to propagate and spread but also to persist in spite of vigorous efforts to destroy it.

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Literature cited

1. **Van Tieghem, P.** Recherches sur la disposition des radicelles et des burgeons dans les racines des Phanérogames. Ann. Sci. Nat. Bot. VII. **5**: 130–151. 1887.
2. **Van Tieghem, P., and H. Duliot.** Recherches comparatives sur l'origine des membres endogènes dans les plantes vasculaires. Ann. Sci. Nat. Bot. VII. **8**: 1–660. *pl. 1–40*. 1888.
3. **Lemaire, A.** Recherches sur l'origine et le développement des racines latérales chez les Dicotylédones. Ann. Sci. Nat. Bot. VII. **3**: 163–274. *pl. 7–12*. 1886.

INDEX TO AMERICAN BOTANICAL LITERATURE
1925–1926

The aim of this Index is to include all current botanical literature written by Americans, published in America, or based upon American material; the word America being used in the broadest sense.

Reviews, and papers that relate exclusively to forestry, agriculture, horticulture, manufactured products of vegetable origin, or laboratory methods are not included, and no attempt is made to index the literature of bacteriology An occasional exception is made in favor of some paper appearing in an American periodical which is devoted wholly to botany. Reprints are not mentioned unless they differ from the original in some important particular. If users of the Index will call the attention of the editor to errors or omissions, their kindness will be appreciated.

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Alderman, W. H., & Shoemaker, J. S. Use of leaf characters in identification of plum varieties. Proc. Am. Soc. Hort. Sci. **22**: 264–269. "1925" 1926.

Allen, R. F. Cytological studies of forms 9, 21, and 27 of *Puccinia graminis tritici* on Khapli emmer. Jour. Agr. Res. **32**: 701–725. *pl. 1–9.* 15 Ap 1926.

Anderson, P. J., Haskell, R. J., Muenscher, W. C., Weld, C. J., Wood, J. I., & Martin, G. H. Check list of diseases of economic plants in the United States. U. S. Dept. Agr. Bull. 1366: 1–112. Ap 1926.

Arnold Arboretum. Publications of the Arnold Arboretum of Harvard University and its staff, 1874–1926, chronologically arranged under authors. 1–19. 1926.

Arthur, J. C. A botanical shrine. Sci. Mo. **22**: 459–462. My 1926.

Home of Linnaeus and the Botanic Garden at Upsala.

Arthur, J. C. The Uredinales (rusts) of Iowa. Proc. Iowa Acad. Sci. **31**: 229–255. "1924" 1925.

Ashe, W. W. Notes on woody plants. Jour. Elisha Mitchell Sci. Soc. **41**: 267–269. Ap 1926.

1 species in *Castanea*, 2 hybrids in *Quercus* and 1 variety in *Magnolia*, described as new.

Barnes, W. C. William E. Safford. Science II. **63**: 418. 23 Ap 1926.

Born 14 December 1859. Died 10 January 1926.

Baxter, D. V. Filibert Roth. Science II. **63**: 348–349. 2 Ap 1926.

Born 20 April 1858. Died 4 December 1925.

Becker, W. Eine neue *Viola* (*V. Dusenii*) aus Brasilien. Repert. Spec. Nov. **22**: 107–108. D 1925.

Belling, J. Single and double rings at the reduction division in *Uvularia*. Biol. Bull. **50**: 355–363. *f. 1–6.* Ap 1926.

Benoist, R. Description d'espèces nouvelles de phanérogames de la Guyane française. Bull. Mus. Natl. Hist. Nat. **31**: 468–469. 1925.

In *Pseudolmedia*, *Piratinera* and *Tachigali*.

Benoist, R. La végétation de la Guyane française. Bull. Soc. Bot. France **72**: 1066–1077. "1925" 15 Mr 1926.

Berger, A. *Mesembryanthemum aureum.* Addisonia **10**: 51–52. *pl. 346.* "D 1925" 8 Ap 1926.

Native of South Africa.

Berger, A. New South American species of *Rubus*. Jour. Washington Acad. Sci. **16**: 160–161. 19 Mr 1926.

Berger, A. The systematic botany of currants and gooseberries. (In Hedrick, U. P. The small fruits of New York. Rept. N. Y. S. Agr. Exp. Sta. **33**^{2}: 254–280. 1925.)

Berger, A. The systematic botany of edible brambles. (In Hedrick, U. P. The small fruits of New York. Rept. N. Y. S. Agr. Exp. Sta. **33**^{2}: 23–85. 1925.)

Several species and varieties in *Rubus* described as new.

Berger, A. The systematic botany of the strawberry. (In Hedrick, U. P. The small fruits of New York. Rept. N. Y. S. Agr. Exp. Sta. **33**^{2}: 371–383. 1925.)

Berkeley, G. H., & Jackson, A. B. *Verticillium* wilt of the red raspberry. Sci. Agr. **6**: 261–270. *f. 1–9.* Ap 1926.

Blake, S. F. Bertoloni's Guatemalan Asteraceae. Bull. Torrey Club **53**: 215–218. 22 Ap 1926.

Blake, S. F. New South American Verbesininae. Jour. Washington Acad. Sci. **16**: 215–227. 19 Ap 1926.

Blake, S. F. *Zinnia* vs. *Crassina.* Rhodora **28**: 40–42. "Mr" 3 Ap 1926.

Blakeslee, A. F., & Cartledge, J. L. Pollen abortion in chromosomal types of *Datura.* Proc. Natl. Acad. Sci. **12**: 315–323. 15 My 1926.

Börgesen, F. Regarding an unauthorized publication on the vegetation of the Virgin Islands. Rhodora **28**: 66–67. "Ap" 11 My 1926.

Referring to the author's "On the vegetation of the Danish West Indies," translated by Fred MacFarlane.

Boswell, V. R. A study of some environmental factors influencing the shooting to seed of wintered over cabbage. Proc. Am. Soc. Hort. Sci. **22**: 380–393. "1925" 1926.

Boynton, K. R. *Berberis Thunbergii.* Addisonia **10**: 59. *pl. 350.* "D 1925" 8 Ap 1926.

Native of Japan.

Boynton, K. R. *Malus glaucescens.* Addisonia **10**: 55. *pl. 348.* "D 1925" 8 Ap 1926.

Native of central United States.

Boynton, K. R. *Malus pulcherrima Scheideckeri.* Addisonia **10**: 53. *pl. 347.* "D 1925" 8 Ap 1926.

Boynton, K. R. *Stigmaphyllon ciliatum.* Addisonia **10**: 57–58. *pl. 349.* "D 1925" 8 Ap 1926.

Native of Brazil.

Brieger, F. G., & Mangelsdorf, A. J. Linkage between a flower color factor and self-sterility factors. Proc. Natl. Acad. Sci. **12**: 248–255. 15 Ap 1926.

Briggs, F. N. Inheritance of resistance to bunt, *Tilletia tritici* (Bjerk.) Winter, in wheat. Jour. Agr. Res. **32**: 973–990. *f. 1–5.* 15 My 1926.

Britton, N. L. Tree-ferns in Porto Rico. Jour. N. Y. Bot. Gard. **27**: 88–90. *f. 4.* Ap 1926.

Brunson, A. M. The relation of inheritance studies to corn improvement. Jour. Am. Soc. Agron. **18**: 308–314. *f. 1.* Ap 1926.

Bull, C. P. Weeds in the fields, gardens and lawns. Minnesota Dept. Agr. Bull. 43: 1–38. *illust.* Mr 1925.

Burkett, J. H. The pecan in Texas, the state tree. The pecan, its history, importance, economic value. Texas Dept. Agr. Bull. 81: 1–218. *pl. 1–50.* My–Je 1925.

Bush, B. F. The Missouri species of *Elymus*. Am. Midl. Nat. **10**: 49–88. Mr–My 1926.

Chamberlain, C. J. Two new species of *Zamia*. Bot. Gaz. **81**: 218–227. *f. 1–6.* 13 Ap 1926.

Z. monticola and *Z. sylvatica*.

Chandler, W. H. Polarity in the formation of scion roots. Proc. Am. Soc. Hort. Sci. **22**: 218–222. *f. 1, 2.* "1925" 1926.

Chase, A. Botanical expedition to Brazil. Smithsonian Inst. Misc. Coll. **78**: 48–54. 1926.

Clark, A. H. The alkaloids of *Ceanothus americanus*. Am. Jour. Pharm. **98**: 147–156. *illust.* Mr 1926.

Clark, H. S. *Corydalis flavula* in Connecticut. Rhodora **28**: 68. "Ap" 11 My 1926.

At Mt. Higby, west of Middletown.

Clos, E. C. Leguminosas forrajeras de la flora Argentina. I, *Medicago* L. (alfalfa, *Lupulina*, tréboles de carretilla). Argentina Min. Agr. Sec. Prop. & Inf. Circ. 595: 1–20. *f. 1–5.* 24 Mr 1926.

Clute, W. N. The meaning of plant names—XXVI, XXVII. Caryophyllaceae. XXVIII. Boraginaceae and others. Am. Bot. **32**: 52–55; 97–105; 148–151. Ap, Jl, O 1926.

Cockerell, T. D. A. The evolution of *Rosa*. Nature **117**: 517. *illust.* 10 Ap 1926.

Coffman, F. A., Tisdale, W. H., & Brandon, J. F. Observations on corn smut at Akron, Colorado. Jour. Am. Soc. Agron. **18:** 403–411. My 1926.

Coker, W. C. Further notes on Hydnums. Jour. Elisha Mitchell Sci. Soc. **41:** 270–286. *pl. 51–65.* Ap 1926.

Collins, G. N. A comparison of maize-breeding methods. U. S. Dept. Agr. Bull. 1396: 1–22. *f. 1–7.* Ap 1926.

Couch, J. N. Notes on the genus *Aphanomyces*, with a description of a new semiparasitic species. Jour. Elisha Mitchell Sci. Soc. **41:** 213–227. *pl. 26–33.* Ap 1926.
A. exoparasiticus described as new.

Coulter, J. M. Searching for fundamentals of plant life. Fruit Belt **24**^{3}: 809. *illust.* Mr 1926.
Researches being carried on at the Boyce Thompson Institute.

Cowdry, E. V. Surface film theory of the function of mitochondria. Am. Nat. **60:** 157–165. Mr–Ap 1926.

Cratty, R. I. The genus *Rumex* in Iowa. Proc. Iowa Acad. Sci. **31:** 213–216. "1924" 1925.

Cratty, R. I. Iowa plant notes. Proc. Iowa Acad. Sci. **31:** 189–192. "1924" 1925.

Crowder, W. Marvels of Mycetozoa. Natl. Geog. Mag. **49:** 421–443. [*16*] *col. pl.* Ap 1926.
Exploration of a swamp at Millneck, Long Island, N. Y.

Cruz, P. I. A viability test for some tropical seeds. Philipp. Agr. **14:** 631–641. Mr 1926.

Dachnowski, A. P. Profiles of peat deposits in New England. Ecology **7:** 120–135. *f. 1, 2.* Ap 1926.

Dandy, J. E. Notes on *Kissenia* and the geographical distribution of the Loasaceae. Kew Bull. Misc. Inf. **1926:** 174–176. *f. 1–7.* Ap 1926.
Includes species from South America.

Davis, W. H. The house fungus *Merulius lacrymans* (Jacq.) Fr. Proc. Iowa Acad Sci. **31:** 169–173. *f. 1.* "1924" 1925.

Dayton, W. A. On *Lupinus fraxinetorum* Greene. Bull. Torrey Club **53**: 157–160. *f. 1, 2* + *pl. 5*. "Mr" 1 Ap 1926.

Deane, W. Further notes on changes in a salt marsh during reclamation. Rhodora **28**: 37–40; 156. "Mr" 3 Ap; "Au" 8 S 1926.

DeLong, D. M. Food plant and habitat notes on some North American species of *Phlepsius*. Ohio Jour. Sci. **26**: 69–72. 26 Ap 1926.

Delwiche, E. J., & Renard, E. Mutations in the pea. Jour. Hered. **17**: 105–106. *f. 9*. 20 Ap 1926.

Demaree, J. B. Little leaf diseases of pecans. Phytopathology **16**: 277–283. *f. 1, 2*. 15 Ap 1926.

Deuber, C. G. Can a pyrrole derivative be substituted for iron in the growth of plants? Am. Jour. Bot. **13**: 276–285. *f. 1, 2*. 15 My 1926.

Dickson, B. T. Further studies on saltation in the organism "black dot" disease of potato. Proc. & Trans. Roy. Soc. Canada III. **19**^{5}: 275–277. *f. 1–7* + *pl. 1*. "1925" 1926.
Colletotrichum atramentarium.

Dickson, J. G. Making weather to order for the study of grain diseases. Wisconsin Agr. Exp. Sta. Bull. 379: 1–36. *f. 1–20*. Ja 1926.

Dickson, J. G., & Holbert, J. R. The influence of temperature upon the metabolism and expression of disease resistance in selfed lines of corn. Jour. Am. Soc. Agron. **18**: 314–322. *f. 1–4*. Ap 1926.

Dodge, A. W. Diagnosing shade tree diseases. Parks & Recreation **9**: 412–417. *illust.* Mr–Ap 1926.

Dorsey, M. J., & Bushnell, J. Plum investigations II. The inheritance of hardiness. Minnesota Agr. Exp. Sta. Tech. Bull. 32: 1–34. *f. 1–3*. D 1925.

Dounin, M. The fusariosis of cereal crops in European Russia in 1923. Phytopathology **16**: 305–308. 15 Ap 1926.

Ducke, A. As Leguminosas do estado do Para. Arch. Jard. Bot. Rio de Janeiro **4**: 211–341. N 1925.

Ducke, A. Plantes nouvelles ou peu connues de la region Amazonienne (IIIe partie). Arch. Jard. Bot. Rio de Janeiro **4:** 1–209. *pl. 1–25.* 1925.

Du Rietz, G. E. Einige von Dr. M. Gusinde gesammelte Flechten aus Patagonien und den Feuerlande. Arkiv Bot. **20B**[1]**:** 1–6. 3 F 1926.

Durrell, L. W., & Lungren, E. A. *Berberis Fendleri*, an alternate host of *Puccinia graminis tritici.* Phytopathology **16:** 234–235. 15 Mr 1926.

Dustan, A. G. A study of the methods used in growing entomophthorous fungi in cages prior to their artificial dissemination in the orchards. Ann. Rep. Entom. Soc. Ontario **55:** 63–67. "1924" 1925.

Eames, E. H. *Hedeoma hispida* in Connecticut. Rhodora **28:** 46–48. "Mr" 3 Ap 1926.

Eames, E. H. *Pogonia affinis* in Maine. Rhodora **28:** 31–34. "F" 1 Ap 1926.

Eckerson, S. H. An organism of tomato mosaic. Bot. Gaz. **81:** 204–209. *pl. 19–22.* 13 Ap 1926.

Epling, C. C. Studies on South American Labiatae. II. Synopsis of the genus *Sphacele.* Ann. Missouri Bot. Gard. **13:** 35–70. *pl. 6, 7.* F 1926.
Several species described as new.

Erwin, A. T. The botanical work of Dr. L. H. Pammel at Iowa State College. Proc. Iowa Acad. Sci. **31:** 139–141. "1924" 1925.

Farr, C. H. The physiology of growth. Proc. Iowa Acad. Sci. **31:** 175–182. "1924" 1925.

Fellows, H. Relation of growth in the potato tuber to the potato-scab disease. Jour. Agr. Res. **32:** 757–781. *f. 1–7 + pl. 1–4.* 15 Ap 1926.

Fennell, R. E. The Polyporaceae of Iowa. Proc. Iowa Acad. Sci. **31:** 193–204. "1924" 1925.

Fernald, M. L. The antiquity and dispersal of vascular plants. Quar. Rev. Biol. **1:** 212–245. *maps 1–10.* Ap 1926.

Fernald, M. L. The ragged orchis of Newfoundland. Rhodora **28:** 21–22. "F" 1 Ap 1926.

Fife, J. M. The effect of sulfur on the microflora of the soil. Soil Sci. **21:** 245–252. *f. 1–5.* Ap 1926.

Fitch, C. L. Observations on physiological reasons for productiveness in seed potatoes. Proc. Am. Soc. Hort. Sci. **22:** 295–303. "1925" 1926.

Fraser, W. P., & Conners, I. L. The Uredinales of the prairie provinces of western Canada. Proc. & Trans. Roy. Soc. Canada III. **19**^{5}: 279–308. "1925" 1926.

[**Ganong, W. F.**] L. W. Bailey. Proc. & Trans. Roy. Soc. Canada III. **19:** xiv–xvii. *port.* "1925" 1926.
Loring Woart Bailey, born 28 September 1839, died 10 January 1925.

Garber, R. J., Odland, T. E., McIlvaine, T. C., & Quisenberry, K. S. Varietal experiments with soybeans. West Virginia Agr. Exp. Sta. Bull. 196: 1–16. *illust.* O 1925.

Geisler, S. Soil reactions in relation to plant successions in the Cincinnati region. Ecology **7:** 163–184. *f. 1–8.* Ap 1926.

Gilchrist, G. C. The nature of resistance to footrot caused by *Ascochyta* sp. and some other fungi in the epicotyl of the pea. Phytopathology **16:** 269–276. *f. 1+pl. 20.* 15 Ap 1926.

Gill, T. The rain forests of the tropics. Nat. Mag. **7:** 297–300. *illust.* My 1926.

Goss, R. W. A simple method of inoculating potatoes with the spindle-tuber disease. Phytopathology **16:** 233. 15 Mr 1926.

Goss, R. W. Transmission of potato spindle-tuber by cutting knives and seed piece contact. Phytopathology **16:** 299–303. *pl. 21.* 15 Ap 1926.

Gothan, W. Sobre restos de plantes; fosiles procedentes de la Patagonia, con un apendice, plantas retucas de Marayes (Prov. de S. Juan). Bol. Acad. Nac. Cien. Argentina **28:** 197–212. *pl. 1–10.* 1925.

Grenzebach, M. A revision of the genus *Bouchea* (exclusive of *Chascanum*). Ann. Missouri Bot. Gard. **13**: 71–100. *pl. 8–12.* F 1926.
Several varieties described as new.

Gress, E. M. Pennsylvania weeds. Pennsylvania Dept. Agr. Gen. Bull. 416: 1–27. *f. 1–14.* 15 N 1925.

Grier, N. M. Device for increasing the capacity of moist chambers. Phytopathology **16**: 309–310. *f. 1.* 15 Ap 1926.

Haller, M. H., & Magness, J. R. The relation of leaf area to the growth and composition of apples. Proc. Am. Soc. Hort. Sci. **22**: 189–196. "1925" 1926.

Halma, F. F. Factors governing the initiation of sprout growth in citrus shoots. Hilgardia **1**: 295–340. *f. 1–11.* Ap 1926.

Hann, R. M., & Sando, C. E. Scyllitol from flowering dogwood (*Cornus florida*). Jour. Biol. Chem. **68**: 399–402. My 1926.

Hansen, A. A. *Trillium*, or wake-robin. Nat. Mag. **7**: 282–284. *illust.* My 1926.

Hardy, Mrs. M. E. New Zealand plants. Am. Bot. **32**: 69–71. Ap 1926.

Harland, S. C. Wither-tip disease of limes; suggestions for its control. Trop. Agr. **3**: 74–75. Ap 1926.

Harley, C. P. Normal variation in the chemical composition of fruit spurs and the relation of composition to fruit bud formation. Proc. Am. Soc. Hort. Sci. **22**: 134–146. *f. 1.* "1925" 1926.

Harris, J. A. The specific electrical conductivity of the leaf tissue fluids of phanerogamic epiphytes. Bull. Torrey Club **53**: 183–188. 22 Ap 1926.

Harshberger, J. W. A comparison of the Alpine regions and vegetation of eastern America, Norway and Switzerland. 1925. (In Festschrift C. Schröter Veroff. Geobot. Inst. Rübel **3**: 271–278.)

Hart, H. Factors affecting the development of flax rust, *Melampsora lini* (Pers.) Lev. Phytopathology **16**: 185–205. *f. 1, 2.* Mr 1926.

Hastings, G. T. Trailing nature. Nat. Mag. **7**: 301–302. *illust.* My 1926.

Hayes, H. K. Present-day problems of corn breeding. Jour. Am. Soc. Agron. **18**: 344–363. Ap 1926.

Hegner, R. W. The interrelations of protozoa and the utricles of *Utricularia*. Biol. Bull. **50**: 239–270. *f. 1–4.* Mr 1926.

Hegner, R. W. The protozoa of the pitcher plant, *Sarracenia purpurea*. Biol. Bull. **50**: 271–276. Mr 1926.

Henry, M. W. The dawn of Wild Flower Day. Am. For. & For. Life **32**: 275–278. *illust.* My 1926.

How a national movement to save woodland flowers originated.

Henshall, (Mrs.) H. F. Index to about 1200 plates of native wild flowers painted in natural colors by Mrs. H. F. Henshall. Bull. Lloyd Lib. 25: 1–32. 1925.

10 volumes in Lloyd Library representing collections from Montana, Mississippi, and vicinity of Tampa, Florida.

Herzog, T. Beiträge zur Moosflora Westpatagoniens. Hedwigia **66**: 79–92. *f. 1–8.* Mr 1926.

Species in *Campylopodium*, *Bryum*, *Macromitrium*, *Jamesoniella* and *Lophocolea*, described as new.

Hirt, R. R. Stratified sporophores of *Polyporus gilvus*. Mycologia **18**: 111–113. 1 My 1926.

Hitchcock, A. S. A basis for agreement on nomenclature at the Ithaca Congress. Am. Jour. Bot. **13**: 291–300. 15 My 1926.

Hoffer, G. N. Some differences in the functioning of selfed lines of corn under varying nutritional conditions. Jour. Am. Soc. Agron. **18**: 322–334. *f. 1–7.* Ap 1926.

Hollick, A. Report on a tree trunk and associated lignitic debris excavated in Manhattan Island. Am. Mus. Novitates 213: 1–6. *f. 1, 2.* 6 My 1926.

Hooker, H. D. Fruit bud formation and growth. Proc. Am. Soc. Hort. Sci. **22:** 123–126. "1925" 1926.

Horne, W. J., Weldon, G. P., & Babcock, E. B. Resistance of peach hybrids. Jour. Hered. **17:** 99–104. *f. 5–8.* 20 Ap 1926.

Howe, M. A. *Dahlia imperialis.* Addisonia **10:** 49–50. *pl. 345.* "D 1925" 8 Ap 1926.
Native of Mexico.

Hurd-Karrer, A. M. Effect of smut on sap concentration in infected corn stalks. Am. Jour. Bot. **13:** 286–290. 15 My 1926.

Huskins, C. L. Genetical and cytological studies of the origin of false wild oats. Sci. Agr. **6:** 303–313. *pl. 1, 2.* My 1926.

Irwin, M. Mechanism of the accumulation of dye in *Nitella* on the basis of the entrance of the dye as undissociated molecules. Jour. Gen. Physiol. **9:** 561–573. 20 Mr 1926.

Jackson, A. B., & Dallimore, W. A new hybrid conifer. Kew Bull. Misc. Inf. **1926:** 113–115. *f. 1–3.* Mr 1926.
Cupressus Leylandii (*C. macrocarpa* Hartw. × *C. Nootkatensis* Don).

Jacques, H. E. A ten year's phenological record of the spring flowering plants of Henry County [Iowa.] Proc. Iowa Acad. Sci. **31:** 225–227. "1924" 1925.

Jehle, R. A., Oldenburg, F. W., & Temple, C. E. Relation of internal cob discoloration to yield in corn. Phytopathology **16:** 207–215. *f. 1, 2.* 15 Mr 1926.

Jones, L. R. Securing disease resistant plants: how important is it: whose job is it. Science II. **63:** 341–345. 2 Ap 1926.

Kelley, A. P. Conservation of our native chestnut. Science II. **63:** 476–477. 7 My 1926.

Kempton, J. H. Maize and man. Jour. Hered. **17:** 33–51. *f. 1–18.* 25 Mr 1926.

Kendrick, J. B. *Holcus* bacterial spot on species of *Holcus* and *Zea mays.* Phytopathology **16:** 236–237. Mr 1926.
Bacterium Holci described as new.

Kidder, N. T. *Erucastrum Pollichii* in Maine. Rhodora **28:** 88. 11 My 1926.
At Rockland.

Kiesselbach, T. A. The comparative water economy of selfed lines of corn and their hybrids. Jour. Am. Soc. Agron. **18:** 335–344. *f. 1–3.* Ap 1926.

Killip, E. P. Botanical investigations at European museums. Smithsonian Misc. Coll. **28:** 54–58. *illust.* 1926.

King, C. M. Viability tests of seeds of different ages. Proc. Iowa Acad. Sci. **31:** 257–264. "1924" 1925.

Klages, K. H. Relation of soil moisture content to resistance of wheat seedlings to low temperatures. Jour. Am. Soc. Agron. **18:** 184–193. Mr 1926.

Kluge, H. C. Trees of the Bayano River watershed, Panama. Trop. Woods Yale Univ. School. For. **5:** 4–13. Mr 1926.

Knott, J. E. Some conditions influencing the determination of catalase activity in plant tissue. Proc. Am. Soc. Hort. Sci. **22:** 398–407. "1925" 1926.

Knowlton, H. E., & Sevy, H. P. The relation of temperature to pollen tube growth in vitro. Proc. Am. Soc. Hort. Sci. **22:** 110–115. *f. 1–3.* "1925" 1926.

Kobuski, C. E. A revision of the genus *Priva.* Ann. Missouri Bot. Gard. **13:** 1–34. *pl. 1–5.* F 1926.
2 species described as new.

Krassovsky, I. Physiological activity of the seminal and nodal roots of crop plants. Soil Sci. **21:** 307–324. *pl. 1, 2.* Ap 1926.

Kraybill, H. R., Potter, G. F., Wentworth, S. W., Blood, P. T., & Sullivan, J. T. Some chemical constituents of fruit spurs associated with blossom bud formation in the Baldwin apple. New Hampshire Agr. Exp. Sta. Tech. Bull. 29: i–xiii, 1–41. *f. 1–20.* D 1925.

Krebs, C. The lotus in northern Ohio. Am. Bot. **32:** 47–49. *illust.* Ap 1926.

Krieger, L. C. C. Sketching fleshy fungi with the aid of the camera lucida. Mycologia **18**: 132–133. *pl. 17.* 1 My 1926.

Kuester, H. L. A chemical study of the rhizome and roots of *Podophyllum peltatum* L. Jour. Am. Pharm. Assoc. **15**: 259–263. *illust.* Ap 1926.

Lantz, H. L. Some observations on the effect of inbreeding on the vigor of apple seedlings. Proc. Am. Soc. Hort. Sci. **22**: 115–123. "1925" 1926.

Leach, J. G. The relation of the seed-corn maggot (*Phorbia fuscíceps* Zeh.) to the spread and development of potato blackleg in Minnesota. Phytopathology **16**: 149–175. *f. 1–13* + *pl. 15.* 15 Mr 1926.

Levene, P. A., & Rolf, I. P. Plant phosphatides. II. Lecithin, cephalin, and so-called cuorin of the soybean. Jour. Biol. Chem. **68**: 285–293. My 1926.

Lloyd, F. E. Sexual reproduction in water silk. Sci. Mo. **22**: 330–340. *f. 1–9.* Ap 1926.

Lloyd, F. E., & Scarth, G. W. The origin of vacuoles. Science II. **63**: 459–460. 30 Ap 1926.

Lombard, L. H. The mullein. Am. Bot. **32**: 68–69. Ap 1926.

Lowie, R. H. The banana in America. Nature **117**: 517–518. 10 Ap 1926.

Author differs with Dr. E. W. Berry on inferences drawn from finding of fossil banana seeds in Tertiary beds in Colombia.

Ludwig, C. A. *Pseudomonas* (*Phytomonas*) *pisi* Sackett, the cause of a pod spot of garden peas. Phytopathology **16**: 177–184. *pl. 16.* 15 Mr 1926.

Macbride, T. H. A bit of Polynesian mycology. Mycologia **18**: 125–131. 1 My 1926.

Badhamia calvescens and *Coremium gracile*, described as new.

McClintock, J. A. Further evidence of uncongeniality in disease-resistant stocks. Proc. Am. Soc. Hort. Sci. **22**: 231–232. "1925" 1926.

MacDaniels, L. H. Pollination studies with certain New York State apple varieties. Proc. Soc. Hort. Sci. **22**: 87–96. "1925" 1926.

MacDougal, D. T. A cycle of the Salton Sea. 1925. (In Festschrift C. Schröter. Veroff. Geobot. Inst. Rübel **3**: 354–363. *illust.*)

McGinty, R. A., & Thompson, R. C. Preliminary notes on tipburn of lettuce. Proc. Soc. Hort. Sci. **22**: 341–346. "1925" 1926.

Mackenzie, K. K. *Aster ericoides* L. Rhodora **28**: 65. "Ap" 11 My 1926.

Mackenzie, K. K. *Solidago rigida* L. Rhodora **28**: 29–31. "F" 1 Ap 1926.

McNamara, H. C. Behavior of cotton root rot at Greenville, Texas including an experiment with clean fallow. Jour. Agr. Res. **32**: 17–24. 1 Ja 1926.

Magness, J. R., & Ballard, W. S. The respiration of Bartlett pears. Jour. Agr. Res. **32**: 801–832. *f. 1–5.* 1 My 1926.

Mains, E. B., Leighty, C. E., & Johnston, C. O. Inheritance of resistance to leaf rust, *Puccinia triticina* Erikss., in crosses of common wheat, *Triticum vulgare* Vill. Jour. Agr. Res. **32**: 931–972. *pl. 1–5.* 15 My 1926.

Martelli, U. A new species of *Pandanus* from Fanning Island. Univ. California Publ. Bot. **13**: 145–146. *pl. 12.* 26 Ap 1926.

P. hermsianus.

Martin, W. H. Plant diseases of New Jersey (ninth instalment). Apple scab and its control. New Jersey Agr. **8**^{4}: 6. *illust.* Ap 1926.

Melchers, L. E. *Botrytis* blossom blight and leaf spot of *Geranium* and its relation to the gray mold of head lettuce. Jour. Agr. Res. **32**: 883–894. *pl. 1–3.* 1 My 1926.

Mellor, E. M. The countries our drugs come from XVII. Jamaica and other Islands of the British West Indies. Pharm. Jour. IV. **62**: 324–328. *illust.* 20 Mr 1926.

Merrill, E. D. Additions to our knowledge of the Philippine flora, II, III. Philippine Jour. Sci. **29:** 475–498. *pl. 1.* Ap 1926; **30:** 389–430. Au 1926.

2 genera of the Rubiaceae, *Boholia* and *Sulitia*, many species and 1 variety, described as new.

Merrill, E. D. The flora of Banquey Island. Philippine Jour. Sci. **29:** 341–429. *f. 1.* Mr 1926.

Mills, W. R. *Lilium michiganense* Farw. in Iowa. Proc. Iowa Acad. Sci. **31:** 265–270. *f. 1, 2.* "1924" 1925.

Moore, B. Influence of certain soil and light conditions on the establishment of reproduction in northeastern conifers. Ecology **7:** 191–220. *f. 1.* Ap 1926.

Moore, G. T., & Carter, N. Further studies on the subterranean algal flora of the Missouri Botanical Garden. Ann. Missouri Bot. Gard. **13:** 101–140. Ap 1926.

Morgan, T. H. Recent results relating to chromosomes and genetics. Quar. Rev. Biol. **1:** 186–211. *f. 1–16.* Ap 1926.

Morris, H. E. Storage dry rot of potatoes. Montana Agr. Exp. Sta. Bull. 183: 1–10. *f. 1, 2.* Ja 1926.

Mowry, H. *Asparagus plumosus.* Florida Agr. Exp. Sta. Press Bull. 384: 1–4. Ap 1926.

Muncie, J. H., & Berkhout, C. Water conduction in apple trees affected with crown gall. Proc. Iowa Acad. Sci. **31:** 143–148. *f. 1, 2.* "1924" 1925.

Navashin, M. Polyploid mutations in *Crepis.* Triploid and pentaploid mutants of *Crepis capillaris.* Genetics **10:** 583–592. *pl. 1.* "N 1925" 22 Ap 1926.

Naylor, E. E. The hydrogen-ion concentration and the staining of sections of plant tissue. Am. Jour. Bot. **13:** 265–275. *pl. 20.* 15 My 1926.

Nichols, G. E. Showy wild flowers that do not need to be protected. Torreya **26:** 17–28. *f. 1, 2.* 24 Ap 1926.

Norlind, V. Beiträge zur Kenntnis der südamerikanischen *Oxalis*-Flora. Arkiv Bot. **20A**^{4}**:** 1–34. *pl. 1–3.* 27 F 1926.

Many species described as new.

Palmer, E. J. Leaves from a collector's note book. Jour. Arnold Arbor. **7:** 136–145. "Ap" 13 My 1926.

Palmer, E. J. The ligneous flora of Hot Springs National Park and vicinity. Jour. Arnold Arbor. **7:** 104–135. "Ap" 13 My 1926.

Pammel, L. H. A century of botany in Iowa. Proc. Iowa Acad. Sci. **31:** 45–68. "1924" 1925.

Pammel, L. H., & King, C. M. Further studies of the germination of woody plants. Proc. Iowa Acad. Sci. **31:** 157–167. *f. 1–11.* "1924" 1925.

Parodi, L. R. La obra botánica del Professor Lucien Hauman. An. Soc. Ci. Argentina **100:** 116–124. Jl–S 1925.

Peattie, D. C. Dr. William Safford. Am. Bot. **32:** 63–66. Ap 1926.

Born 14 D 1859. Died 10 Ja 1926.

Pfeiffer, N. E. Microchemical and morphological studies of effect of light on plants. Bot. Gaz. **81:** 173–195. *f. 1–4 + pl. 15.* 13 Ap 1926.

Phillips, D. The dragon's-tongue. Am. Bot. **32:** 50–52. *illust.* Ap 1926.

Pittier, H. On *Gyranthera* and *Bombacopsis*, with a key to the American genera of Bombacaceae. Jour. Washington Acad. Sci. **16:** 207–214. *illust.* 19 Ap 1926.

Plagge, H. H. Soft-scald and breakdown of apples as affected by storage temperature. Proc. Am. Soc. Hort. Sci. **22:** 58–66. "1925" 1926.

Potter, G. F., & Kraybill, H. R. Fruit spur composition in relation to fruit bud formation. Proc. Am. Soc. Hort. Sci. **22:** 146–150. "1925" 1926.

Poulter, R. W. Some winter-flowering plants. Proc. Iowa Acad. Sci. **31:** 271–274. *illust.* "1924" 1925.

Purdy, H. A. Attempts to cultivate an organism from tomato mosaic. Bot. Gaz. **81:** 210–217. 13 Ap 1926.

Ramaley, F. Outlines of economic botany for laboratory and reference study. 1–30. 2d ed. rev. Boulder, Col., 1926.

Ravens, L. The large yellow lady's slipper. Nat. Mag. **7**: 159. *illust.* Mr 1926.
Cypripedium pubescens.

Redles, G. The persistence of some of our native plants. Torreya **26**: 28–29. 24 Ap 1926.

Reid, M. E. Growth of seedlings in relation to composition of seed. Bot. Gaz. **81**: 196–203. *pl. 16–18.* 13 Ap 1926.

Rhoads, A. S. Diseases of grapes in Florida. Florida Agr. Exp. Sta. Bull. 178: 75-156. *f. 1–87.* Ja 1926.

Richards, B. L. Seed-potato treatment for the control of four common diseases, *Rhizoctonia*, scab, blackleg and dry-rot. Utah Agr. Exp. Sta. Circ. 60: 1–14. *f. 1–7.* Mr 1926.

Richards, B. L., & Bracken, A. F. Control of stinking smut of wheat with copper carbonate. Utah Agr. Exp. Sta. Circ. 59: 1–8. *f. 1, 2.* F 1926.

Richmond, T. E. Longevity of the legume nodule organism. Jour. Am. Soc. Agron. **18**: 414–416. My 1926.

Richmond, T. E. The nodule organism of the cowpea group. Jour. Am. Soc. Agron. **18**: 411–414. My 1926.

Riley, L. A. M. Revision of the genus *Calycolpus*. Kew Bull. Misc. Inf. **1926**: 145–154. Ap 1926.
Several tropical American species and varieties.

Roberts, J. W., & Dunegan, J. C. Blossom blight of the peach. Phytopathology **16**: 217–222. Mr 1926.

Roberts, J. W., & Pierce, L. Apple blotch. U. S. Dept. Agr. Farmers Bull. 1479: 1–12. *f. 1–8.* Ap 1926.

Roberts, J. W., & Pierce, L. Apple Scab. U. S. Dept. Agr. Farmers Bull. 1478: 1–12. *f. 1–7.* Ap 1926.

Robinson, J. Plants growing the first season in an uncovered cellar. Rhodora **28**: 69–74. 11 My 1926.
Plants collected in cellars of South Church and vestry, Salem, Mass., Oct. 14 and 17, 1904.

Rodrigo, P. A. A case of polyembryony in rice. Philippine Agr. **14:** 629–630. *pl. 1.* My 1926.

Rose, D. H. Relation of strawberry fruit rots to weather conditions in the field. Phytopathology **16:** 229–232. Mr 1926.

Rose, J. N. *Pitcairnia exscapa.* Addisonia **10:** 63–64. *pl. 352.* "D 1925" 8 Ap 1926.
Native of Ecuador and Colombia.

Rose, J. N., & Leonard, E. C. *Pachylophus marginatus.* Addisonia **10:** 61–62. *pl. 351.* "D 1925" 8 Ap 1926.
Native of western United States.

Rosen, H. R. Bacterial stalk rot of corn. Phytopathology **16:** 241–268. *f. 1–5 + pl. 17–19.* Ap 1926.

Rosen, H. R. A new *Amanita* from Arkansas. Mycologia **18:** 97–99. *pl. 9–11.* 1 My 1926.
A. arkansana.

Rudolph, B. A. *Verticillium* wilt of tomatoes in California. Phytopathology **16:** 234. Mr 1926.

Ruef, J. U., & Richey, H. W. A study of flower bud formation in the Dunlap strawberry. Proc. Am. Soc. Hort. Sci. **22:** 252–260. "1925" 1926.

Rusby, H. H. Additions to the genus *Lycianthes* (Dunal) Hassler. Bull. Torrey Club **53:** 209–213; 302. 22 Ap; "My" 3 Je 1926.
Several species and combinations described as new.

Ryan, R. W. The development of the perithecia in the Microthyriaceae and a comparison with *Meliola.* Mycologia **18:** 100–110. *pl. 12–15.* 1 My 1926.
Amazonia Laguncularae described as new combination.

Rydberg, P. A. Botanizing in the higher Alleghany Mountains —III. North Carolina. Jour. N. Y. Bot. Gard. **27:** 80–88. Ap 1926.

Rydberg, P. A. Notes on Fabaceae—VII. *Geoprumnon* Rydberg. Bull. Torrey Club **53:** 161–169. "Mr" 1 Ap 1926.
Species in *Hesperastragalus* described as new.

Rydberg, P. A. Two new species from the mountains of West Virginia. Torreya **26:** 28–33. *pl. 2.* 24 Ap 1926.
Aconitum vaccarum and *Heuchera alba.*

Sando, C. E. The coloring matter, quercimeritrin, from the double chrysanthemum-flowered sunflower (*Helianthus annuus*). Jour. Biol. Chem. **68:** 407–414. My 1926.

Sando, C. E. Inositol from blackberry (*Rubus argutus* Link) and flowering dogwood (*Cornus florida*). Jour. Biol. Chem. **68:** 403–406. My 1926.

Sandwith, N. Y. Humboldt and Bonpland's itinerary in Ecuador and Peru. Kew Bull. Misc. Inf. **1926:** 181–190. Ap 1926.

Sanford, S. N. F. A new station for *Cyperus erythrorhizos.* Rhodora **28:** 67. "Ap" 11 My 1926.
Westport, Bristol County, Massachusetts.

Schaffner, J. H. The nature and cause of secondary sexual states with special reference to *Typha.* Bull. Torrey Club **53:** 189–208. 22 Ap 1926.

Schaffner, J. H. Questionnaire on certain facts bearing on the theory of sexuality and chromosome constitution. Science II. **63:** 384–385. 9 Ap 1926.

Schlechter, R., & Hoehne, F. C. Contribuicoes ao conhecimento das orchidaceas do Brasil (Beiträge zur Orchideenkunde Brasiliens). Arch. Bot. Est. S. Paulo **1:** 165–349. *illust.* 1925.

Schmidt, O. C. Beiträge zur Kenntnis der flora Westindiens I. Repert. Spec. Nov. **22:** 93–99. D 1925.

Schorger, A. W. David Douglas—blazer of tree trails. Am. For. & For. Life **32:** 262–264. *port.* My 1926.
Born 1798. Died 1834.

Seaver, F. J. Mycological work in Bermuda. Jour. N. Y. Bot. Gard. **27:** 90–93. *f. 5.* Ap 1926.

Shaffer, E. T. H. The Ashley River [South Carolina] and its gardens. Natl. Geog. **49:** 525–550. [*16*] *col. pl.* My 1926.

Shamel, A. D., Pomeroy, C. S., & Caryl, R. E. Bud selection in the Washington navel orange. VI. Progeny test of a dual limb variation. Jour. Hered. **17:** 59–65. *f. 20–23.* "F" 25 Mr 1926.

Shear, C. L., & Clements, F. E. The condition and needs of systematic mycology. Science II. **63:** 393–395. 16 Ap 1926.

Shelford, V. E., Shreve, F., Braun, E. L., Korstian, C. F., Dice, L. R., Miller, R. B , Jones, L., Gaige, H. T., & Baker, F. C. Naturalists' guide to the Americas. i–xv, 1–761. *f. 1–16.* Baltimore, Williams & Wilkins, 1926.

Shimek, B. The prairie of the Mississippi River bluffs. Proc. Iowa Acad. Sci. **31:** 205–212. *f. 1, 2.* "1924" 1925.

Shoemaker, J. S. Pollen development in the apple, with special reference to chromosome behavior. Bot. Gaz. **81:** 148–172. *pl. 12–14.* 13 Ap 1926.

Shreve, F. The desert of northern Baja California. Bull. Torrey Club **53:** 129–136. *f. 1, 2.* "Mr" 1 Ap 1926.

Skottsberg, C. Vascular plants from the Hawaiian Islands. I. Meddel. Goteborgs Bot. Tradgard **2**^{2}: 185–284. *f. 1–9.* 1925–1926.

Small, J. K. A new bellflower from Florida. Torreya **26:** 35–36. 24 Ap 1926.
Campanula Robinsiae.

Small, J. K. A new palm from the Mississippi delta. Torreya **26:** 33–35. 24 Ap 1926.
Sabal Deeringiana.

Smith, C. O. Similarity of bacterial diseases of avocado, lilac and citrus in California. Phytopathology **16:** 235–236. 15 Mr 1926.

Smith, F. F. Pseudo-fertility in *Nicotiana.* Ann. Missouri Bot. Gard. **13:** 141–172. *f. 1–4.* Ap 1926.

Smith, L. B. Three plants of Plymouth, Massachusetts. Rhodora **28:** 88. 11 May 1926.
Eupatorium leucolepis, Scirpus debilis Williamsii, and *Psilocarya nitens.*

Smith, O. Some changes in the relations of plants and soil caused by sterilization of soil with steam. Proc. Am. Soc. Hort. Sci. **22**: 323–330. "1925" 1926.

Sommer, A. L. Studies concerning the essential nature of aluminum and silicon for plant growth. Univ. California Publ. Agr. Sci. **5**: 57–81. *f. 1, 2.* 6 My 1926.

Soth, Mrs. M. E. The weed flora of Pocatello, Idaho. Am. Bot. **32**: 55–59. Ap 1926.

Sponsler, O. L. Molecular structure of plant fibers determined by x-rays. Jour. Gen. Physiol. **9**: 677–695. *f. 1–10.* 20 My 1926.

Sprague, T. A. The international names of three orchid genera. Jour. Bot. **64**: 109–113. Ap 1926.
Genera represented by *Epipactis*, *Serapias* and *Goodyera*.

Sprague, T. A., & Green, M. L. Alphabetical list of nomina rejicienda (Phanerogamae). Kew Bull. Misc. Inf. **1926**: 128–141. Mr 1926.

Stallings, J. H. The form of legume nitrogen assimilated by non-legumes when grown in association. Soil Sci. **21**: 253–276. Ap 1926.

Stancliff, J. O. South Sea fruit. Am. Bot. **32**: 59–62. Ap 1926.

Stevens, N. E., & Sawyer, W. H., Jr. The distribution of cranberry false blossom. Phytopathology **16**: 223–227. Mr 1926.

Sturtevant, A. H. Reuner's studies on the genetics of *Oenothera*. Quar. Rev. Biol. **1**: 283–288. Ap 1926.

Symons, J. L. Studies in the genus *Xanthium*. Bot. Gaz. **81**: 121–147. *pl. 9–11.* 13 Ap 1926.

Tapke, V. F. Single-bath hot-water and steam treatments of seed wheat for the control of loose smut. U. S. Dept. Agr. Bull. 1383: 1–29. *f. 1–4.* Mr 1926.

Thomas, H. E. Root and crown injury of apple trees. Cornell Agr. Exp. Sta. Bull. 448: 1–9. Mr 1926.

Toro, R. A. La influencia del ambiente en la proteccion de las plantas contra enfermedades. Porto Rico Insular Exp. Sta. Circ. 90: 1–10. 1925.

Trelease, S. F., & Trelease, H. M. Toxicity and antagonism in salt solutions as indicated by growth of wheat roots. Bull. Torrey Club **53**: 137–156. *f. 1–5.* "Mr" 1 Ap 1926.

Trelease, W. New Piperaceae from South America and Mexico. Jour. Washington Acad. Sci. **16**: 204–207. 19 Ap 1926.
Species in *Piper* and *Peperomia.*

Tucker, C. M. La enfermedad de la raiz del cafe en los semilleros. Revista Agr. Puerto Rico **16**: 129–130. Mr 1926.

Turner, T. W. The effect of varying the nitrogen supply on the ratios between the tops and roots in flax. Soil Sci. **21**: 303–306. Ap 1926.

Uppal, B. N. Relation of oxygen to spore germination in some species of the Peronosporales. Phytopathology **16**: 285–297. 15 Ap 1926.

Valleau, W. D., Kenney, R., & Kinney, E. J. Root-rot of tobacco in Kentucky and its control (a progress report). Kentucky Agr. Exp. Sta. Bull. 262: 157–180. *f. 1–6.* D 1925.

Vaughan, R. E., & Wellman, F. L. Club root of cabbage. Wisconsin Ext. Serv. Circ. 200: 1–4. *illust.* Ap 1926.

Vinall, H. N. Charles Vancouver Piper. Jour. Am. Soc. Agron. **18**: 295–300. Mr 1926.
Born 16 Je 1867. Died 11 F 1926.

Wade, B. L. The development and inheritance of a defective endosperm in maize. West Virginia Agr. Exp. Sta. Bull. 197: 1–20. *f. 1–4.* Jl 1925.

Walpole, B. A. Distribution of *Hymenophysa pubescens.* Science II. **63**: 335. 26 Mr 1926.

Weatherby, C. A. A new *Magnolia* from west Florida. Rhodora **28**: 35–36. "F" 1 Ap 1926.
M. Ashei.

Weatherby, C. A., Knowlton, C. H., & Bean, R. C. Fifth report of committee on floral areas. Preliminary lists of New England plants—XXX. Rhodora **28**: 43–46. "Mr" 3 Ap 1926.

Wehmeyer, L. E. Further cultural life histories of the stromatic Sphaeriales. Am. Jour. Bot. **13**: 231–247. *pl. 12–15.* 26 Ap 1926.

Weinstein, A. I. Cytological studies on *Phaseolus vulgaris.* Am. Jour. Bot. **13**: 248–263. *f. 1 + pl. 16–19.* 26 Ap 1926.

Wellman, F. L. Occurrence of club root on Chinese cabbage. Phytopathology **16**: 310. Ap 1926.

Wherry, E. T. Nitrogen as a factor in plant distribution on Mt. Desert Island, Maine. Ecology **7**: 140–142. Ap 1926.

Whetzel, H. H., & Kern, F. D. The smuts of Porto Rico and the Virgin Islands. Mycologia **18**: 114–124. *pl. 16.* 1 My 1926.

Tolyposporella Sporoboli described as new.

White, C. T. Ligneous plants collected in New Caledonia by C. T. White in 1923. Jour. Arnold Arbor. **7**: 74–103. "Ap" 13 My 1926.

Gymnospermae enumerated by E. H. Wilson; Angiospermae determined by A. Guillaumin.

Wiegand, K. M. *Oxalis*, a correction. Rhodora **28**: 67. "Ap" 11 My 1926.

Wilber, C. P. Is the American chestnut coming back? Am. For. & For. Life **32**: 349. *illust.* Je 1926.

Willard, C. J. Do legume leaves hasten the curing process by pumping moisture from the stems? Jour. Am. Soc. Agron. **18**: 369–375. My 1926.

Wilson, E. H. *Thuja orientalis* Linnaeus. Jour. Arnold Arbor. **7**: 71–74. *pl. 1.* "Ap" 13 My 1926.

Winter, J. D. Use of plant characters in identification of red raspberry varieties. Proc. Am. Soc. Hort. Sci. **22**: 261–264. "1925" 1926.

[**Wodehouse, R. P.**] Plants which cause hayfever. 1–36. *f. 1–45.* Arlington Chemical Company, Yonkers, N. Y., 1925.

Wolfe, H. S. The auximone question. Bot. Gaz. **81**: 228–231. 13 Ap 1926.

Woolard, E. W. Trees favored and hated of Jove. Am. For. & For. Life **32**: 259–261. *illust.* My 1926.

Assumed preference of lightning for certain species.

Zirkle, C. The structure of the chloroplast in certain higher plants. I, II. Am. Jour. Bot. **13**: 301–320; 321–341. *pl. 21–27.* 15 My, 18 Je 1926.

Corrections on INDEX in December Bulletin

Dodge, B. O. Organization of the telial sorus in the pine rust, *Gallowaya pinicola* Arth. Jour. Agr. Res. **31**: 641–652. *f. 1 + pl. 1, 2.* "1 O" D 1925.

Girola, C. D. Plantas medicinales. Argentina Min. Agr. Nac. Sect. Prop. Inf. Circ. 231: 1–84. *illust.* 1924.

Marsh, C. D., Clawson, A. B., & Roe, G. C. Nuttall's death camas (*Zygadenus Nuttallii*) as a poisonous plant. U. S. Dept. Agr. Bull. 1376: 1–13. *f. 1–3.* F 1926.

Rehder, A. New species, varieties and combinations from the herbarium and the collections of the Arnold Arboretum. Jour. Arnold Arbor. **7**: 22–37; 145–149. "Ja" 4 Mr; "Ap" 13 My 1926.

In *Taxodium, Pinus, Clematis, Ribes, Exochorda, Malus, Pyrus, Ribes, Pyconia, Rubus, Glochidion, Euonymus, Vitis, Tilia, Rhododendron, Syringa, Campsis,* and *Lonicera.*

Smith, H. H. European botanical gardens. Wisconsin Hort. **15**: 172–174. *illust.* Jl 1925; **16**: 22–23. O 1925; 34–35. N 1925; 50–51. D 1925; 66–67. Ja 1926; 82–83, 87. F 1926.

Walcott, M. V. North American wild flowers. v. 1. *col. pl. 1–80,* with text. Washington, D. C., Smithsonian Inst., 1925.

Wieland, G. R. The El Consuelo Cycadeoids. Bot. Gaz. **81**: 72–86. *f. 1.* 22 Mr 1926.

The haustoria of certain rusts and the relation between host and pathogene[1]

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(WITH PLATES 1–9)

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INTRODUCTION

The relations of host and parasite in the case of plants infected by the higher fungi whose structure is so highly differentiated afford a specialized field for the study of fundamental pathogenic relations. The following study of haustoria has been undertaken with the aim of contributing toward the solution of the problems of susceptibility and immunity and the relations between the higher parasitic fungi and their hosts.

Probably the earliest mention of haustoria is that of Visiani of the Venetian Commission which reported upon the grape mildew in 1851. Von Mohl (1863) reports that Visiani claimed

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that 'Haft-organe' upon the surface of the leaf send penetrations 'nach Art von Wurzeln in das Gewebe der Epidermis.' Von Mohl discredits the idea of cell penetrations and figures only 'Haft-organe' for the grape mildew. DeBary (1863) was the first to describe adequately the occurrence and structure of haustoria. He apparently first used the term haustorium for the knob-like organs of *Cystopus*. He described and figured many examples of haustoria in the Peronosporeae and in the Erysipheae. Through DeBary's studies in the Erysipheae, Visiani is confirmed. In Vergleichende Morphologie und Biologie der Pilze (1884) DeBary reproduced Von Mohl's figure of *Erysiphe Tuckeri*, which shows 'Haft-organe' only, and on the same page figured attachment disk and haustorium for *Podosphaera Castagnei*. He included the attachment disk as a typical part of the structure, describing the haustoria as 'Haft- und Saug-organe.' He correctly regarded the haustorium as a specialized organ that maintains the interrelations between parasite and host. The most careful of the modern studies upon haustoria has been made in the group of the Erysipheae by Grant Smith (1900).

Work upon haustoria in the Uredineae seems to have developed more slowly than in the other groups of fungi. In 1863 DeBary stated that he had first thought haustoria in the Uredineae were limited to perennial species but that he had found them also in non-perennials. In 1867 he described the branched and knotted haustoria of *Aecidium elatinum*. Somewhat vague drawings of haustoria for both *Puccinia Malvacearum* and *Uredo graminis* were given by Carlo Bagnis (1875). Ward (1882) was the first to present detailed work upon haustoria of the Uredineae, when he described and figured the haustoria of *Hemileia vastatrix*. Ward's later work (1902, 1904) upon *Uredo dispersa* in the brome grasses centered the problems of parasitism in the Uredineae upon the haustorium.

The bearing of the haustorial relation between host and pathogene upon the nature, origin, and development of parasitism has been but little developed since Ward's introduction. Many simple and obvious questions as to the structure and function of haustoria cannot be regarded as settled. Are they purely nutritive, and is the haustorium the most perfect and least destructive means by which a parasite can draw food from a host?

Does it, on the other hand, imply destructive attack by physical or by chemical means? Does it imply toxic action of the parasite on the host, or does the presence of haustoria imply high resistance in the host as compared with the ineffectual resistance of the host to *Pythium* or *Botrytis?* How does the penetration of the wall by a haustorium compare with the intracellular parasite in its relations to its host? Data upon such questions relate directly to important problems of susceptibility and immunity.

REVIEW OF LITERATURE

The evolutionary classification of parasitism in the fungi

The question of the origin and nature of parasitism itself underlies questions concerning haustoria. Have parasites developed from saprophytes? In the field of bacteriology, Oscar Bail argues for such an origin, and suggests that the search for food may have led a saprophyte into the bodies of living animals. Infection is defined by Bail (1911) as the colonization of an organism within the same space which another organism fills with its own functioning. He applies his theory in a classification of bacteria, which he calls an attempt at a natural system of infective organisms. On the basis of their invasive power he recognizes: first, the pure saprophytes which can under no conditions colonize within foreign organisms, the necro-parasites, like the tetanus bacillus, which enter living hosts through dead tissues and overcome the host cells by toxins; second, the half parasites of the typhus type, whose successful infection is limited to definite body regions, and whose poisons are bound to the bacterial body; finally, the pure parasites, which, with increased aggressiveness and power of infection, have little of toxicity: '. . . je besser sie das Infizieren gelernt haben, nicht ihren Nährboden früher zerstören, ehe sie ihn nicht überall ausgenützt haben.' The organisms producing septicemia he gives as an example of this third type.

Theobald Smith (1921) likewise develops the idea of an evolutionary series of bacteria, classified by the character of their invasive power. At one end of the scale, he places types just emerging from the predatory or saprophytic stage and acquiring parasitic habits; at the other end, the highly specialized forms adapted to one host, species, or race. Agents of septic infection illustrate the saprophytic predatory type. Next he places the semi-saprophytic diphtheria bacillus, which offers a direct offensive to the host body by toxins that attack and injure living tissues. (These are Bail's necro-parasites.) Then he notes an adapted type where the offensive devices of invasion are under control, such as the tubercle bacillus with which the host frequently establishes a balanced life. Finally, he notes the development of the highly specialized parasite, such as the smallpox organism, which 'depends upon one host for its existence' and has established such a balance with that host as to be able to complete a full life cycle of invasion, multiplication, and dissemination. There are, Smith adds, no obstacles to the activity of these organisms except immunity.

DeBary (1884) turned the attention of mycologists to the physiological viewpoint by his painstaking work upon structure and function in the fungi. He was apparently the first mycologist to attempt an evolutionary classification of the fungi on a physiological basis. Unlike the bacteriologists with their emphasis upon invasive power, he based his classification on degrees of adaptation in obtaining nutrition. He distinguished: first, pure saprophytes; second, the facultative parasites, species normally saprophytes but with the power of going through their development wholly or in part as parasites; third, the facultative saprophytes, which as a rule go through the whole course of their development as parasites (indeed a parasitic life is indispensable to the attainment of their full development) but which are able in certain stages to vegetate as saprophytes; finally, the obligate parasites, species which live only as parasites.

Van Tieghem (1873) used the term facultative parasitism in connection with *Chaetocladium*, *Piptocephalis*, and *Syncephalis*, to indicate a parasitism 'avantageux sans doute, mais non necessaire.' In explanation he refers to several degrees of parasitism leading to one which implies 'une condition absolue d'existence,' but DeBary was apparently the first to balance the term obligate against facultative. DeBary (1884) removed *Piptocephalis*, *Syncephalis*, and *Chaetocladium*, the group for which Van Tieghem coined the phrase facultative parasites, to the group of facultative saprophytes on the ground that they form zygospores only when they live as parasites.

DeBary places the rusts together with the lichen fungi at the head of the obligate parasites. This linking is made upon the basis of the limited host accommodation on the part of both rusts and lichen fungi, the character by which DeBary recognizes the extreme of obligate parasitism. In discussing the effects on the host and the reactions of the host, he separates the rusts and the lichen fungi. He places many rusts, such as the species of *Puccinia* infecting grasses, in the group of destructive fungi. The other rusts he places in the group which cause in varying degree in their hosts 'mycetogenetic metamorphosis.' He places the lichens at the head of this group. In this, as well as in his main divisions, DeBary's emphasis is upon nutrition. He regards all these grades of parasitism as 'in direct causal connection with the process of feeding on the part of the fungus.' Raines (1922) goes a step further by tracing an interaction between obligateness and mutualism:

> In the group of the fungi the transition from violent and destructive parasitism to parasitism of the symbiotic type is accompanied by a transition from facultative to obligate parasitism as if the physiological corollary of parasitism of the latter type is extreme specialization in food preferences.

The real relation between these classifications of the bacteriologists and mycologists is in need of further study. In the classifications of bacteria quoted above, the basis is that of attacking power of the parasite, while for the mycologists the basis is that of method of nutrition. The two views are not inconsistent. Indeed the quotation from Raines indicates how functions of offence and of nutrition may interact. An understanding of both the method of nutrition and the change from the production of toxic products to the production of neutral products, so far as the host is concerned, is necessary in a full analysis of the interrelations of two cells achieving structural as well as functional adaptations toward symbiosis.

To a greater or less degree one finds presented in various handbooks on fungi the conception of an evolution from saprophytic to obligate parasitic types. Frank (1895) divides parasitic fungi into an obligate and a facultative group, making the possibility of artificial culture the characteristic of the facultative parasite, over against those which can be brought to a complete development only upon a living host. However, instead of treating the obligate as the climax of an evolution, he considers the method of attack of a facultative parasite the stronger, since 'the conditions of its entrance and development in this case are much broader.'

Massee (1899) regards parasitism as an acquired condition, and he traces gradations in injury to the host. He commences with *Pythium*, which 'lacking experience, kills its host plant within a very short period, thus limiting its own existence to a matter of hours.' (Here we have Smith's semi-saprophyte.) At the other extreme he places organisms that have evolved a method of living with the host plant with comparatively little injury to it—as for instance the smuts, which in many cases cause little or no injury during the vegetative period of the host; the parasite of *Lolium temulentum* which hibernates in the aleurone layer of the seed and lives in such complete mutualism as an intercellular parasite through the whole life cycle of the host that all spore production on the part of the fungus has been eliminated; and the cereal rusts, which attack only specific hosts and by means of haustoria live for long periods in intracellular relations with them.

Klebahn (1912) begins his evolutionary discussion with the spot fungi, which, he states, are parasitic in attack, but become saprophytes, causing death of the tissue by poison enzymes. He illustrates varying degrees of this toxic action as found in *Botrytis*, *Pythium*, *Phytophthora*, *Septoria*, and *Gleosporium*. Over against this class, which causes a more or less early death of the host tissue, stand, in Klebahn's list, those strict parasites which grow through the tissue and nourish themselves thereon without killing. Here the browning of tissue is less in evidence. There may be fading or yellowing or there may be the occurrence of new color (anthocyan). In this class of strict parasites Klebahn places the Uredineae, Ustilagineae, and Oömycetes. These groups, according to Klebahn's description, would rank with the adapted type of bacterial parasites for which Smith emphasizes immunity as the only obstacle.

Butler (1918) presents the most detailed physiological classification found in any of the handbooks. He traces the parasitic strain as one 'educated' from hemi-saprophytes, parasitic only occasionally on 'weak hosts,' through wound parasites, to those able to attack sound tissues. The true parasites he subdivides on the basis of variations in methods of feeding.

The references given indicate that DeBary's classification is generally recognized; but the relatively small space given the discussion in the various handbooks indicates that a physiological classification of fungi in their relations to the substratum is still only in the stage of a working hypothesis. That it may be more than a working hypothesis in the future, Blackman (1924) forecasts as follows: 'We may anticipate a time when these hidden reactions (the physiological processes of the parasite) may be revealed and a new basis for the classification of plant diseases established.'

In this connection, the facultative parasites are of special interest since here one probably finds the parasitic habit in its beginning and one may contrast the evidence of toxic action by the invading hyphae of the non-haustorial facultative parasite with the evidence of fine adjustment to its host on the part of the obligate haustorial parasite. *Botrytis* and the related Pezizas are instructive types of this facultatism. Indeed Ward (1890) states in his Croonian lecture that it is apparently possible to carry the process of 'educating' the *Botrytis* genus to habits of parasitism much further than in any other cases known. His description in this lecture of the behavior of a *Botrytis* illustrates the non-adapted habit of a fungus which succeeds in devouring its young soft host:

> So long as the protoplasm can dispose of small amounts of poison coming in from the hyphae, the hypha is debarred access to the cells but immediately the poison succeeds in lessening or destroying the power of the protoplasm to control the cell sap, the latter exudes through the permeable protoplasm and suffuses the whole tissue with the cell sap, containing just such food materials as the fungus flourishes in. The fungus can flourish while these products last; but the death of the host tissue results in the early end of the food supply.

The *Botrytis* hypha is here an instrument of destruction and is a very successful instrument of its kind. There is specialization in the case of the saprophyte, which consumes the whole body of the host at once, but the more successful type requires of its host continuous small quantities of food for a long period. This is the habit of an adapted parasite.

In *Peziza Sclerotiorum*, DeBary (1884) describes the beginnings of parasitism, for, although he cultured the fungus as a saprophyte on a variety of media, he proved that it would attack healthy tissue also, provided that the spores were first germinated under saprophytic conditions. He believed that penetration into the host membrane is effected by aid of a ferment, which can be formed only by a properly nourished germ tube. DeBary was not able to obtain a conidial stage for his *Peziza*, but its relationship to *Botrytis* is generally accepted. Ward implies this in his comparison of DeBary's results and his own work with a lily-*Botrytis*. Of the latter he writes (1888): 'I am driven to conclude that although I have never yet succeeded in growing sclerotia or peziza-cups from the *Botrytis* it is either a stage in the life history of a *Peziza* of some kind or at least its alliance lies in this direction.' Of DeBary's fungus he writes: 'Accepting DeBary's results with *Peziza Sclerotiorum*, I regard his fungus as a form physiologically midway between the ordinary saprophytic Pezizas, and my parasitic one; in other words, DeBary's fungus is in process of being educated to parasitic habits.' Ward offers his lily-*Botrytis* as illustrating the next higher step in parasitism, because of its power of direct penetration into living tissue. This unusual instance of a *Botrytis* able to penetrate a living host unaided, he explains as due to the water-gorged state of the lily tissue caused by an excessively rainy season, but the variable power of the fungus, he believes, is shown by a differential behavior within the host tissue. He finds in the infected lily plants not only cases of the normal *Botrytis* saprophyte, where the fungus ferment kills the tissue, and the mycelium is trapped in the shrivelled mass of brown dead cells, but also cases where the invader, although destructive to adjacent cells, is able to advance to new areas through the water-soaked walls. Thus within one tissue one may see the shift from the predatory saprophyte to the half parasite. In addition to the added power of penetration into the soft host, the essential difference lies in a finer adjustment between invader and host, which brings death less quickly as the result of infection.

Ward concluded that his lily-fungus was 'a so-called *Botrytis* of the *Polyactis* type—distinct from *Polyactis vulgaris*, *Botrytis cinerea* and other accepted forms.' Later work adds evidence of the complexity of this type. Klebahn (1909), working with *Botrytis cinerea* on *Syringa*, *Pelargonium*, and *Adiantum*, concluded that 'under the name *Botrytis cinerea* many forms are assembled which have developed in varied degree the power to infect and are also in part more or less adapted to quite definite hosts.' He found a considerable degree of parasitism for the species, along with some specialization in hosts. Conidia from *Syringa* leaves infected *Syringa* readily, but infected *Pelargonium* and *Adiantum* in decreasing degree. Conidia from *Pelargonium*, however, gave vigorous infection upon *Syringa*. In all cases, he stated, the infection occurred without any preliminary saprophytic nourishment, and without any artificial injury or killing of the host tissue. We have here a further advance in the facultative parasitism of *Botrytis*.

The connection between a *Botrytis* and a *Sclerotinia* has been established by Seaver and Horne (1917). They obtained the *Botrytis* form directly from the peziza cups of sclerotia on rhizomes of *Geranium maculatum*. The cultures were similar to the conidial stage, which was also abundant upon the *Geranium*. *Sclerotinia Geranii* appears from their description to be a specific parasite.

Brierly (1919) from the genetical standpoint supports the assumption of a multiple *Botrytis*. He is unable, he states, to 'educate' *Botrytis cinerea* unless the initial culture consists of a mixed population.

A further indication of specificity in the relation of *Botrytis* to different hosts is confirmed and illustrated by Hopkins (1921) in his study of *Botrytis Tulipae*. Not only was its parasitism demonstrated by numerous infections of tulips from pure cultures, but gradations in parasitism were shown by the weaker and varying ability of the pathogene to attack such other plants as narcissus, onion, crocus, and hyacinth.

The specificity in host relations in this case, however, does not necessarily imply an advance in adaptive parasitism. There may be here merely the preference of a fungus for one food over another; but from this tendency an omnivorous saprophyte may develop physiological species, and may even evolve into a parasite upon a favorable host. Thus the later studies upon *Botrytis* really corroborate the ideas of DeBary and Ward as to the evolution of parasitism. Both in the occasional finer adjustment between invader and host which brings death less quickly as the result of infection, and in tendencies toward specificity in hosts, this example of a facultative parasite suggests something of the manner of life of the haustorial fungus. However, it is only facultative parasitism at the most, and *Botrytis* in general illustrates what the obligate parasite with haustoria does not do.

This is emphasized by Ward (1890), who concludes his discussion of the relation between host and parasite by balancing against his description of *Botrytis* and its host relations a description of conditions among the Uredineae: 'In all cases where haustoria are developed, the mycelium enters into a peculiar symbiotic connection with the cells and for some time merely taxes them as it were rather than injures them directly.' Such phenomena, Ward believes, 'tend to the subject of symbiosis proper where relations between host and parasite have become so arranged that both may be said to benefit by the commensalism.'

Thomas (1921) also brings out the same contrast in parasitic habits when he outlines an intergrading series of parasites according to completeness of adaptation to the host. Commencing with *Botrytis*, which kills in advance, he points to the increasing tendency among various parasites to show features of mutualism and symbiosis as adaptation becomes more nearly complete. He regards the seed fungus of *Lolium temulentum* as a climax form, since 'it is perpetuated entirely as a mycelium through the seed of the host and perhaps never kills any of the host cells.'

The tendency of parasites to increase reproduction at the expense of vegetative growth and differentiation is almost universal. The group of the Rhizoctonias and *Lolium* are, however, marked exceptions, which seem to perpetuate themselves entirely, or largely, by mycelium or sclerotia. *Corticium vagum Solani*, the basidial stage demonstrated by Rolfs (1904) for the *Rhizoctonia* on the potato, does not seem necessary for perpetuation of the fungus. Duggar and Stewart (1901) and Rolfs (1904) think that *Rhizoctonia* may live indefinitely as a soil saprophyte and infect the potato under conditions unfavorable to host growth. Whether the seed fungus and the sterile Rhizoctonias represent the highest degree of specialization physiologically is a question dependent upon how the suppression of spore production is to be interpreted. Vegetative growth may itself be a drain upon a host. The thread blight of tea, a possible *Rhizoctonia* described by Butler (1918), produces no spores but causes a browning of the tea leaf under the heavy web of mycelium. *Corticium vagum Solani* is at any rate proved a more specialized parasite than its *Rhizoctonia* stage. Rolfs states of the *Corticium* stage: 'This stage has been observed only on or near green potato plants. . . . All attempts in the laboratory to develop spores on various culture media have failed.' Peltier (1916), who has found the *Corticium* stage on a number of garden plants, observes: 'This stage is generally found on plant tissues that are perfectly healthy; it is in no way injurious to them.'

The rusts, in contrast to these characterless organisms which have apparently lost in differentiation, show a high degree of specificity in spore forms.

Relations between host cells and intracellular parasites

Two types of intracellular fungi are familiar: first, the common case in which mycelial hyphae merely pierce and grow through the host cells, as do *Pythium* and *Rhizopus;* second, the case in which the hyphae form special coils or wefts in the host cells, as do the fungi of certain Mycorrhizas, or live entirely within the host cell, as do certain Chytridiaceae.

Piercing host cells by haustorial processes seems to be a very different thing from piercing host cells by entering hyphae, as in the case of *Pythium.* Higgins (1914) describes a *Septoria* whose hyphae pass directly through cells of *Prunus pennsylvanica*, killing the leaf tissue outright. Stevens and Hawkins (1917) show that *Rhizopus* causes 'leak' in the strawberry by piercing the cells and killing the protoplasts. Hawkins and Harvey (1919) claim that *Pythium* in the potato tuber punctures by pressure, and then kills the invaded cells by toxins.

The haustorial penetration shows analogies to the behavior of the unicellular, intracellular, parasitic fungi. The method of penetrating the host cell and the interrelations of the protoplasm of host and parasite in these cases should throw light on the nature of haustoria and their functions. The haustorium is, at least so far as the cell wall is concerned, an intracellular portion of a parasite which is otherwise intercellular with respect to its host. So far as we know haustoria are primarily absorption organs, although specific evidence as to what and how they absorb is as yet lacking. They seem to effect an increased contact area between host and fungus, approximating that maximum contact attained by such intracellular parasites as the tubercle organisms of legumes, the parasitic Myxomycetes, and the Chytridiaceae.

Absorption following 'leaking' of the host cell is, for bacterial parasites, apparently the common method in both plant and animal hosts. It is the method described by Bachmann (1913) for *Bacillus amylovorus*, by Riker (1923) for the crown gall organism in tomato stems, and by Wolf (1924) for the bacterial pustule of soy bean.

The root-tubercle organism has a different life history. Its morphology and physiology have presented difficult problems to both pathologist and physiologist since Eriksson observed the tubercles in the Leguminosae. The early history of the work is adequately outlined by Dawson (1899). She states that Beijerinck (1888) finally isolated the organism and named it *Bacillus radicicola*, and that he concluded that the much debated 'filaments' were composed of bacteria embedded in mucilaginous cell walls, by means of which they are protected from the action of the cell-plasm. Peirce (1902) in his work upon the root-tubercles of Bur Clover gives a different interpretation of the contact conditions. Peirce used a combination of the Gram and the triple stains, whereby the positive-staining bacteria appear purple in the host cells against the orange of the host cytoplasm. In the later stages he shows the two colors fused to a dull gray with no demarcation between the two protoplasms. He states of an infected cell that the cytoplasm is crowded with bacteria. Thus Peirce describes an intimate host-parasite contact even at the stages when others have said the bacteria are discharged from the jelly into the host cell cavity. The existence of the condition described by Peirce calls for further study, but if confirmed the condition would seem to imply a relation between host and parasite protoplasm that prevents their forming surface films when in contact. Buchanan (1909) demonstrated the zoogloeal matrix to be of carbohydrate nature, arising from the diffluent cell walls of the bacteria, and he found a certain degree of racial differentiation in the varying ability of the legume organisms to form this gum.

Certain highly specialized parasitic slime molds and a series of parasitic Chytridiaceae include perhaps the most carefully studied cases of intracellular parasites. These slime molds are apparently for a time parasitic in the host cells without killing them. Nawaschin (1899) describes the symbiotic relationship between *Plasmodiophora Brassicae* and the cells of the host as long continued. The fungus lives, he says, only in the vacuoles and seemingly does not disturb the normal life functions of these cells until, just before spore formation, the host nuclei and cytoplasm are crowded to the walls by the increase of amoebae. Ward (1901) refers to this fungus as a contrast to the saprophytic *Pythium*. The presence of the entire protoplasmic body of one organism in the cell of another, 'each living its own life for the time being, but the protoplasm of the host cell showing clearly by its abnormal behavior that the presence of foreign protoplasm is affecting its physiology,' is a case, he says, 'of tolerance on the part of the host which adapts itself to the altered circumstances by marked adaptations.' Osborn (1911) reports for *Spongospora subterranea* the same absence of disturbing effects upon the host during the amoeboid life of the fungus.

Lutnam (1913) describes an intimate relation between the plasmodium of *Plasmodiophora* in its early stages and the host protoplasm: 'The plasmodium of the fungus is clear and almost transparent at first, the outlines being difficult to distinguish as they blend with the protoplasm of the host.' The older plasmodium, he says, may be recognized by its abundant oil globules and practically fills the cell lumen, pushing the host protoplasm to the wall. The infected cells are stimulated to hypertrophy and hyperplasy, but only upon approach to spore formation is there degeneration of the host nucleus. Kunkel has worked with both *Spongospora subterranea* (1915) and *Plasmodiophora Brassicae* (1918). He agrees with the reports of earlier workers in the matter of mutualism, but he describes closer contact conditions between fungus and host protoplasm, an actual mingling, as it seems to him, of the two. He shows drawings of *Spongospora subterranea* invading healthy tissue, pushing down between the cells, and finally infecting them by sending small protoplasmic strands through the softened cellulose walls. He did not determine the method by which the plasmodium penetrates the host protoplasm, but he shows stages where the plasmodium has not gone far into the protoplasm; where it has just reached the host nucleus; and where it completely surrounds the latter, apparently directly in contact with the nuclear membrane. Kunkel opposes the earlier conceptions of Nawaschin: 'The plasmodium in the host cell does not appear to be in a vacuole or to be separated from the host protoplasm by a membrane of any kind. The one seems to be somewhat miscible in the other.' He states that the invaded cells are stimulated by the plasmodia to increased growth and division, but that during all this activity the host nucleus shows little distortion and can sometimes be found intact within the spore balls, a further proof of the specialized parasitism of *Spongospora subterranea*. For *Plasmodiophora Brassicae*, Kunkel traces, in the cortex and the cambium of the cabbage, successive stages in the penetration of the protoplast by the plasmodium. In both these fungi, Kunkel states, the symbiotic relation between host and parasite is so balanced that most of the injury is due to secondary causes. Clearly, these three intracellular organisms, *Pseudomonas*, *Spongospora*, and *Plasmodiophora*, show a high state of mutualism in their relations to their hosts, and they all agree in showing close contact relations between the host cells and the invading protoplasts.

Certain Chytridiaceae show perhaps the most extended host-parasite contact relations reached by intracellular parasites. Such a case is that of *Physoderma Zeae* as described by Tisdale (1919). The delicate outgrowths from the zoospores penetrate the epidermal cell walls of the corn, and thence fine fibers invade a number of the surrounding parenchyma cells, forming within these cells 'enlarged cell groups.' In Tisdale's figures these 'Sammelzellen' seem embedded in the host protoplasm, and according to his report, they have no defined boundary. The host cells appear at this time to be merely slightly enlarged, but by the time the invading bodies have developed into sporangia, the host cells are dead and their protoplasm is almost completely destroyed. As in the case of the Myxomycetes, the mutualism breaks down upon sporulation.

The climax of development of these intracellular growths attained by the parasitic Chytridiaceae is found in *Urophlyctis Alfalfae* as described by Jones and Drechsler (1920). Their figures show the extreme of intracellular parasitic growth processes. From the invaded epidermal cell the processes of the fungous protoplast spread through the sub-adjacent cells of the parenchyma. The resting spore also develops a zone of repeatedly branched projections. Their figures show the host protoplasm close against these branching processes of the fungus. It is by no means a clear case of invagination in the drawings, and Jones and Drechsler do not state their opinion upon this point, but they state the lobes function in the assimilation of food material for the spore. On this ground the increased contact surface which the processes afford justifies their phrase, 'branched haustorial processes.'

According to the detailed figures of Leitgeb (1881), *Completoria complens* branches within the cells of fern prothalli into a lobed mass much like that of *Physoderma*, and like it, sends processes into neighboring cells. Here, however, the host sets up a definite reaction. A thickening of the host cellulose seemingly delays penetration and later sheaths the base of the process. This seems to be a clear case of invagination. Leitgeb was able to see chloroplasts carried by the streaming protoplasm of the host around the invading body. Whatever the relationship of this little parasite, whose structure is superficially so like that of the Chytridiaceae, its symbiotic adaptations are more like those of the higher fungi, where the haustorium is so general in occurrence.

Fungous parasites producing haustoria

The occurrence of haustoria

As reported in the literature, haustoria occur in certain species at least of all the great groups of hyphal fungi, the Oömycetes, Zygomycetes, Ascomycetes, and Basidiomycetes. The instances which I have found reported in the literature are listed below, arranged according to the classification of Engler and Prantl's Natürlichen Pflanzenfamilien (1897–1900). A comparison of these occurrences affords specific evidence on the question as to whether the existence of haustoria may be considered an index of the grade of specialization in the relation of host and parasite. In the Zygomycetes, their occurrence is limited to one small division. In the three great groups, the Oömycetes, the Ascomycetes, and the Basidiomycetes, there are subdivisions in which their occurrence is practically universal.

OÖMYCETES:

- Pythium palmivorum, E. J. Butler (1910). The only example of haustoria reported for this group.
- Albugo candida; haustoria were probably first described in this species; DeBary (1863).
- Peronosporaceae; haustoria are reported for practically all genera of this group.

ZYGOMYCETES: In this predominately saprophytic group haustoria are reported only in the cases of *Piptocephalis*, *Syncephalis*, and *Chaetocladium*, the forms for which Van Tieghem (1873) coined the term facultative parasite. The haustorium of *Chaetocladium*, as described by Burgeff (1920), is more exactly an intermediate cell, in which cytoplasm and nuclei of host and parasite are intimately mingled.

ASCOMYCETES:

Taphrina maculans, Butler (1918).
Coccomyces (Cylindrosporium Padi), Higgins (1914).
Hysterostomella, Lembosia, Parmularia, Arnaud (1918).
Meliola, a genus possessing highly specialized haustoria, Maire (1908), Arnaud (1918), Doidge (1920).
Irene, Doidge (1920).
Erysiphaceae; haustoria are reported for practically all genera of this group, including the probable first mention of haustoria by Visiani (1851) and the detailed work by G. Smith (1900).
Parodiella, Arnaud (1918).
Dimerosporium, Arnaud (1918).
Asterina, Maire (1908), Arnaud (1918).
Acanthostigma parasiticum, Ducomet (reported by Butler, 1918).
Trichosphaeria parasitica, Hartig (1882).
Trabutia quercina, Arnaud (1910).
Podocapsa, Van Tieghem (Reported by Engler and Prantl, 1897).

FUNGI IMPERFECTI:

Darluca filum, Sappin-Trouffy (1896), Clinton (1904), Adams (1920).
Septogloeum Hartigianum, Hartig (1892).
Cylindrosporium Padi, Higgins (1914).
Tuberculina persicina, Sappin-Trouffy (1896).

MYCELIA-STERILIA:

Cuticularia Ilicis, Ducomet (1907).

BASIDIOMYCETES; HEMIBASIDII: In general haustoria are regarded as typical for the group. Lutman (1910) and Sartoris (1924) claim that the presence or absence of haustoria is a distinguishing characteristic between the two main groups. The Ustilaginaceae, they state, lack haustoria, while the Tilletiaceae have haustoria. They correlate this structural difference with a physiological difference. *Ustilago*, they note, infects growing points where food is easily accessible. *Tilletia* occurs in leaf and stem tissues where food is less concentrated. The following reports indicate that this generalization is not absolute for the Ustilaginaceae. Reports agree upon the presence of haustoria in the Tilletiaceae.

USTILAGINACEAE; Absence of haustoria:

Ustilago Zeae-Mays, Knowles (1889), Lutman (1910).
U. laevis, Lutman (1910).
U. Tritici, Butler (1918).
U. Hordei, U. Heufleri, U. Tritici, U. Zeae, Sartoris (1924).

USTILAGINACEAE; Presence of haustoria:

Ustilago Carbo, U. hypodytes, U. longissima, U. Maydis, Fischer von Waldheim (1869).
Ustilago, many species, Tubeuf (1897).

U. Sorghi (broom-corn), Clinton (1897).
U. Zeae-Mays, Guttenberg (1905).
U. striaeformis, Osner (1916).
U. Avenae, U. Hordei, Butler (1918).
Cintractia Seymouriana, P. Magnus (1867).
Sorosporium Saponariae, Fischer von Waldheim (1867), Tubeuf (1897).

PROTOBASIDII; UREDINALES: The two reports following are the only cases I have found in which haustoria are said to be lacking:
Aecidium Urticae on *Urtica dioica*, Schroeter (1875);
Coleosporium Pini on *Pinus virginiana*, Galloway (1896).

The morphology of haustoria

There are occasional references in the literature which imply that the haustorium is an independent cell. Sappin-Trouffy (1896) in some cases finds a partition at the base of the haustorial stalk in *Puccinia graminis* on oats. G. Smith (1900) states that such septa occasionally present themselves, and he figures two cases for *Erysiphe graminis*. R. E. Smith (1905) figures the haustoria of *Puccinia Asparagi* as stubby branches partitioned off from the hyphae. Guttenberg (1905) states that the branched and bent haustoria of the corn smut are abundantly septate. Colley (1918) is undecided as to whether the haustorium of *Cronartium ribicola* is always cut off from the hypha which forms it. Dodge (1923) writes of the haustoria of *Gymnoconia interstitialis* on the dewberry:

> The haustoria are often provided with short, more or less twisted and intertwined branches; in this case they are composed of several cells, each cell with a single nucleus. Such complex haustoria are more in the nature of intracellular hyphae, and nearly fill the cell attacked.

The more general view of the haustorium as a protrusion from a hyphal cell is held by Allen (1923):

> The empty haustorium mother cell remains plump. . . . This would suggest that when the cell contents entered the host cell to form the haustorium, at least a thin membrane was left behind lining the cell wall of the mother cell, and that this membrane is continuous through the membrane of the haustorium inside the host cell.

In a few cases haustoria with broad necks have been described. The absence of constriction is like that found in some penetrating hyphae of facultative parasites, such as *Botrytis* and *Rhizopus*. Sappin-Trouffy (1896) figures a broad neck for the haustorium of *Uromyces Ficariae* on *Ficaria ranunculoides*. The haustoria described by R. E. Smith (1905) for *Puccinia Asparagi* seem merely stubby hyphal branches. There is no evidence of constriction either in the early protuberance or the later short blunt lobe. Blackman (1904) figures a broad neck for the haustorium of *Phragmidium violaceum* on *Rubus fruticosus.*

The slender neck is, however, most typical for haustoria. Sappin-Trouffy (1896), with reference to *Uromyces Erythronii*, speaks of the narrow hollow pedicel of the haustorium, which gives some communication with the cavity of the hypha. Exceptional length in slender stalks may be noted in such forms as *Hemileia vastatrix* (Ward, 1882), *Erysiphe Cichoracearum* (G. Smith, 1900) and *Meliola amphitricha* (Doidge, 1920).

The great variety of form found in the absorption sac is evidently an individual working out by the parasites of a differentiation to effect increased surface of contact.

These forms fall readily into the four classes of haustoria, which Arnaud (1918) distinguishes in his studies on the Asterineae. They are as follows: (1) The simple haustorium, spherical, pyriform, reniform, straight or bent. (2) The spiral haustorium, derived from class 1 by a lengthening and spiral rolling of the type. (3) The digitate haustorium, where diverticula extend more or less at right angles from the central stalk. (4) The coralloid haustorium, formed of short clustered ramifications from a basal stalk.

Among the many species described by Arnaud the following have especially complicated haustoria: *Asterelibertia Conepiae, Parodiopsis Ingarum, Trabutia quercina, Lembosia Melastomatum, Patouillardia clavispora,* and *Perisporiopsis splendens.*

The coralloid type, so abundant in the Asterineae, and also, according to Lutman, abundant in the Ustilagineae, is the rare form in the Uredineae. Sappin-Trouffy's descriptions of over thirty rusts do not afford an illustration. The only good example which I find reported is that of *Botryorrhiza Hippocrateae* (Olive, 1918).

Variations of form in haustoria as influenced by host conditions are reported in many instances in the literature. Nuclear contact as a form stimulus is indicated by Vuillemin's description of a *Puccinia* upon *Thesium* (1894). The haustoria when remote from the host nucleus are simple vesicles; when in contact with the nucleus they branch from a broad basal sac into a tuft of short lobes. Sappin-Trouffy (1896) records variations for rusts in different tissues. *Puccinia graminis* shows simple claviform haustoria in the sclerenchyma of oats, and twisted, irregularly branched forms in its parenchyma; while *Puccinia graminis* in the barberry shows both types of haustoria in the parenchyma. A similar variation of form in one mycelium infecting different tissues is given by Evans (1907). He finds that the haustoria of *Puccinia glumarum* in the cells surrounding the vascular bundles of the host are much branched, while those in the chlorenchyma are small club-shaped bodies. An abnormal haustorial form due apparently to age of the fungus is described by Tischler (1911) in infected rhizomes of *Euphorbia Cyparissias*, from which all intercellular mycelium had died out and disappeared. These haustorial remains resemble a knot of tangled hyphae, showing clearly septation and a binucleate condition of the cells. Tischler fitly calls this an intracellular haustorial pseudoparenchyma. Arnaud (1918) also notes a variation in different host tissues. He reports that *Lembosia Melastomatum* forms digitate haustoria in the palisade cells of its host, but forms simple elongate sacs in the sclerenchyma fibres. Arnaud reports that the variety of form found in haustoria of the Asterineae is much greater in dicotyledonous than in monocotyledonous hosts. Dodge (1922) comments upon the different forms of haustoria of *Gymnosporangium clavipes* in its two hosts. He finds in the tissues of *Crataegus* coils of irregular hypha-like haustoria; in *Juniperus*, trim binucleated haustoria.

The probable importance of the nucleus of the haustorium is commented upon by Harper (1896) in a study of *Sphaerotheca Castagnei*. According to reports in the literature, the number of nuclei in the haustorium varies greatly. Sappin-Trouffy (1896) figures a digitately branched haustorium for *Uromyces Ficariae*, with two nuclei in the broad stalk and other nuclei in the lobes. Holden and Harper (1903) show, in figures of *Coleosporium Sonchi-arvensis*, a binucleate haustorium, and another where one of the conjugate nuclei is still in the extracellular hypha, concluding that without doubt the nuclei are plastic enough to be elongated in order to pass through the haustorial neck. Gibson (1904) reports that haustoria of *Uredo Chrysanthemi* have often as many as five nuclei. Evans (1907) reports as many as five nuclei in the haustoria of *Puccinia glumarum*. This is interesting in connection with his statement that the hyphae of this rust are crammed with nuclei. The two nuclei which Lutman

TABLE I

Number of nuclei in the haustorium in the gametophytic and sporophytic generations

DATE	AUTHORITY	SPECIES	HOST	GAMETOPHYTE	SPOROPHYTE
1896	Sappin-Trouffy	Coleosporium Senecionis	Senecio vulgaris		2
		Gymnosporangium Sabinae	Juniperus Sabina		1
		G. Sabinae	Pirus communis	1	
		Melampsora betulina	[Betula]		2
		Puccinia fusca	Anemone nemorosa	1	
		P. graminis	Avena		1 or 2
		P. graminis	Berberis	1	
		Peridermium Pini	Pinus sylvestrus	1	
		Phragmidium subcorticium	Rosa		2
		Uromyces Betae	Beta		2
		Uromyces Erythronii	Frittilaria Meleagris	generally 1	
1900	W. Magnus	Puccinia leucospermum	Anemone nemorosa	2	
1903	Holden and Harper	Coleosporium Sonchi-arvensi	Solidago and Aster		2
1904	Ward	Uredo dispersa	Brome grasses		usually 1
1904	Blackman	Phragmidium violaceum	Rubus fruticosus		2
1907	Evans	Puccinia glumarum			
		P. graminis			2 or more often 5
1911	Tischler	Uromyces Pisi	Euphorbia Cyparissias	1	
1916	Clinton and McCormick	Cronartium ribicola	Pinus Strobus	1 or 2	
1917	Kursanov	Melampsora Pyrolae	Pyrola rotundifolia		2
1918	Colley	Cronartium ribicola	Pinus Strobus	1	
		C. ribicola	Ribes		2
1922	Dodge	Gymnosporangium clavipes	Juniperus virginiana		2
1923	R. Allen	Puccinia graminis Tritici	Triticum		2
1923	Thurston	Gymnosporangium bermudianum	Juniperus barbadensis J. virginiana J. bermudiana	1*	1*

* 'In *Gymnosporangium bermudianum* the two kinds of mycelium exist side by side in a very close relationship within a single gall and each produces its spore form apparently unhampered in any way by the presence of the other . . . . The haustoria of *G. bermudianum* . . . both from gametophytic and aporophytic mycelium contain regularly one nucleus.'

(1910) shows as characteristic of the huge haustorium of *Entyloma Nympheae*, and of the small knobbed haustorium of *Urocystis Anemones*, lie in the broad stalk from which the many branches rise. Lutman suggests that this is probably the most favorable position for the performance of functions in relation to the whole haustorium. Istvánffi and Palinkás (1913) find a single nucleus typical for the haustorium of *Plasmopara viticola*, but in the larger haustoria they find often two, three, or even four nuclei. Only one of these, they say, migrates into the haustorium, the rest being formed by division in the haustorium. The huge coralloid haustorium of *Botryorrhiza Hippocrateae*, as described by Olive (1918), is multinucleate. Allen (1923) calls attention to elongated nuclei in the hyphal runners of *Puccinia graminis Tritici*. She thinks that those which Evans interpreted, in the runners of cereal rusts, as cases of amitosis must also have represented a normal condition. I have often found these elongated nuclei in the hyphae of the corn rust. Their form makes the entrance of nuclei through the narrow necks of the corn haustoria seem very possible.

Table 1 gives the number of nuclei as reported in the literature for haustoria arising from presumably gametophytic and sporophytic mycelia.

Most authors agree that there is a wall around the haustorium, although there are differences of view as to the relation of age to the thickness of the wall. It is possible that the haustorium sheath is not always distinguished from the wall. The following authors give varying reports as to the thickness of the wall. Sappin-Trouffy (1896) describes a thin membrane bounding the vacuolate granular protoplasm of the branched haustoria of *Uromyces Erythronii*, and a thick membrane around the haustoria of *Coleosporium Senecionis*. In the case of *Uromyces Betae*, whose haustoria vary through simple, branched, and corkscrew forms, he notes an increasing thickness of wall in direct ratio to complexity of form, until the membrane of the corkscrew forms is thicker than that of the hyphae. G. Smith (1900) distinguishes a haustorium wall as well as a sheath of altered host cellulose. Maire (1908) distinguishes a membrane for the haustoria of *Meliola* and *Asterina*. For *Meliola* he describes a brown membrane with a distinct lumen for the stalk, and a thin hyaline membrane for the ampulla. For *Asterina* he describes a hyaline, but often thick, layered membrane around the hyphal branches of the knotted haustorium. Istvánffi and Palinkás (1913) state that the membrane of the haustorium of *Plasmopora viticola* is somewhat thicker than that of the hyphae. Doidge (1923) figures for *Irene matulensis* the same slender-stalked type of haustorium that Maire has shown for *Meliola* but states that its brown walls are thinner than those of the mycelium. Allen (1923) mentions for the haustoria of *Puccinia graminis Tritici* a delicate limiting membrane.

The following authors relate the thickening wall to aging of the haustorium. Ward (1882), describing the haustoria of *Hemileia vastatrix*, states that in older specimens a distinct wall is evident. Evans (1907) notes for *Puccinia glumarum* that as the haustoria become older their walls become thick and stain deeply. Butler (1907) states for *Sclerospora graminicola* that the young haustorium has a thin wall before the deposit of a cellulose cap. Colley (1918) states that the wall of the haustorium of *Cronartium ribicola* is at first quite thin, but that it thickens as the sheath develops.

Relations between haustorium and host cell

Invagination. I have found no definite claim in any case that the haustorium penetrates the primordial utricle and lies in the central vacuole of the host cell. The following workers make no mention of the relation, and show host cytoplasm in their figures indefinitely or not at all:

Anderson, *Aecidium elatinum* (1897); Evans, Cereal rusts (1907); Stämfli, Rust galls (1909); Pritchard, *Puccinia graminis* (1911); Reed and Crabill, *Gymnosporangium Juniperi-virginianae* (1915); Osner, *Ustilago striaeformis* (1916); Arnaud, Perisporiaceae (1918); Adams, Peridermiums (1919); Weston, *Sclerospora philippinensis* (1920); Whitehead, *Urocystis Cepulae* (1921); Moss, Pucciniastreae (1926).

The following workers describe or figure invagination of the host cytoplasm by the haustorium:

Leitgeb, *Completoria complens* (1881); DeBary, The adapted parasite (1884, 1887); Groom, Mycorrhiza on *Thismia Aseroe* (1895); G. Smith, Erysipheae (1900); Ward, *Uredo dispersa* (1904); Tischler, *Uromyces Pisi* (1911); Klebahn, Haustorial fungi (1912); Istvánffi and Palinkás, *Plasmopora viticola* (1913);

Colley, *Cronartium ribicola* (1918); Dodge, *Gymnosporangium fraternum* (1918); Olive, *Botryorrhiza Hippocrateae* (1918); Allen, *Puccinia graminis Tritici* (1923); Thurston, *Gymnosporangium bermudianum* (1923).

Contact between haustorium or other intracellular cells of the parasite and the host nucleus. The question of contact between haustorium and host nucleus has received much attention. The following lists summarize the claims upon the subject in the literature.

No definite contact between haustorium and host nucleus is reported by Werner Magnus, Mycorrhiza in *Neottia Nidus-avis* (1900); G. Smith, Erysipheae (1900); Holden and Harper, *Coleosporium Sonchi-arvensis* (1903); Moss, Certain species of Pucciniastreae (1926).

Occasional contacts, without evidence of any constancy, are reported by Vuillemin, *Puccinia Thesii* (1894); Ward, *Uredo dispersa* (1904); Blackman, *Phragmidium violaceum* (1904); Guttenberg, *Uromyces Alchemillae* (1905); Colley, *Cronartium ribicola* (1918); Dodge and Adams, *Peridermium cerebrum* (1918); Adams, *Peridermium Comptoniae* (1919).

Definite contact relations between host nucleus and haustorium or intracellular cells of parasite are reported by Rosen, *Puccinia asarina* (1893); Groom, Mycorrhiza on *Thismia Aseroe* (1895); Harper, *Sphaerotheca Castagnei* (1896); Sappin-Trouffy, Uredineae (1896); Magnus, *Puccinia leucospermum*, *P. Xanthii*, *Roestelia cancellata* (1900); Peirce, *Pseudomonas radicicola* (1902); Němec, Mycorrhiza in *Calypogeia* (1904); Whetzel, *Peronospora Schleideniana* (1904); Guttenberg, *Puccinia Adoxae*, *Ustilago Maydis* (1905); Evans, *Puccinia Sorghi* (1907); Lutman, Ustilagineae (1910); Zach, *Puccinia glumarum*, *P. graminis* (1910); Arzberger, Mycorrhiza in *Myrica cerifera*, *Eleagnus argentea*, and *Ceanothus americanus* (1910); Tischler, *Uromyces Pisi* (1911); Clinton and McCormick, *Cronartium ribicola* (1916); Allen, *Puccinia graminis Tritici* on Khapli emmer (1926); Moss, *Thecopsora Vacciniorum* on *Vaccinium canadense* and *V. pennsylvanicum*, and other species of the Pucciniastreae (1926).

Sheathing of the haustoria or other intracellular cells of the parasite. The presence of sheaths which are apparently deposits of cellulose from the host cell has been described by DeBary (1863) for the penetrating germ tubes of *Peronospora Radii*, and by Leitgeb (1881) for the penetrating filaments of *Completoria complens* in fern prothalli. Brefeld and Istvánffi (1895) figure smut-infected oats, and show holes bored in the cuticle, below which the ensheathed germ-tubes may be followed. Lutman (1910) also describes this germ-tube sheath for *Ustilago laevis*.

Sheathed intracellular hyphae are characteristic of many Ustilagineae. Sheaths enclosing the invading hyphae in certain Ustilagineae were reported by Fischer von Waldheim (1869). His descriptions include *Ustilago Maydis*, *Ustilago Carbo*, *Sorosporium Saponariae* and *Urocystis occulta*. The mycelial strands, he says, are completely encased by a thick cellulose sheath. Reinhold Wolff (1873) describes the same phenomenon for *Urocystis occulta* in rye. Lang (1899), reporting upon the endophytic fungus in the gametophyte of *Lycopodium clavatum*, states that the hypha in passing through the basal wall of the rhizoid is surrounded by a short sheath derived from the perforated cell wall. Guttenberg (1905) has not only verified sheathing for the corn smut, but sees in it a protective reaction of the host plasm controlled by the nucleus.

DeBary (1863) figures a sheath about the haustorium of *Cystopus candidus* in cortical parenchyma of *Tragopogon*, and about the haustorium of *Peronospora Umbelliferarum* in a leaf of *Aegopodium Podagraria*. After describing the haustoria of *Aecidium elatinum* (1867) he adds that many of them fail to penetrate the walls of the host cells and are covered by a thickened, shining sheath. DeBary (1884) explains the cellulose sheath as due to the continued action of a pellicle of the living host cell, which forms a close sheath around the intruder.

Mangin (1895) reports that the haustorial sheaths in the Peronosporeae consist of a cellulose more resistant than ordinary, by reason of the association of a second substance, callose, with the cellulose. Ordinarily, he says, the haustoria have a double envelope, and between these two one often sees irregular and voluminous masses of callose, which at times cause the rupture of the external membrane. At other times he finds that the outer membrane consists only of callose and forms a complete sheath around the haustorium, sometimes so massive as to crowd the host protoplasm to the wall.

By far the most detailed study of sheath formation has been made by G. Smith (1900) working on the haustoria of the Erysipheae. Smith reports that the first stage of penetration by a haustorium is indicated on the outer surface of the leaf by the appearance of a clear shining area around the point of penetration. At the same stage the inner surface of the cell wall immediately under the point where the hypha comes in contact with the epidermis stains deeply. The wall thickens over an area coinciding roughly with the clear space noted. Smith holds that the density of the cellulose indicates actual growth in thickness, rather than swelling, such as Ward describes for *Botrytis*. This thickening of the wall for some time keeps in advance of the growing tube of penetration, forming a knob-shaped papilla in the cell, but gradually, he believes, the haustorium digests this. Finally the mature haustorium lies in a cavity filled with products of the dissolved cellulose sheath and bounded by the invaginated plasma membrane. Around its slender stalk a collar of cellulose remains, which seems continuous with the cell wall.

A very remarkable cellulose formation is described by Němec (1904) for *Calypogeia Trichomanis* stimulated by mycorrhizal fungi. The fungus forms a pseudoparenchymatous tissue of intracellular hyphae, from which slender haustoria penetrate in such numbers into adjacent cells that a surface view of a wall so entered looks like a sieve. In many cells the haustoria never perforate the cellulose projections which sheath them. Often a whole wall may thicken to inclose a series of haustoria.

Ducomet (1907) describes a heavy sheath with a roughened granular surface around the haustoria of the subcuticular fungus *Cuticularia Ilicis*.

In the case of the East Indian Maize mildew, *Sclerospora graminicola*, Butler (1907) finds both the hyphae and the haustoria sheathed. The invasion hyphae are similar to those which Wolff described for the smuts. They run intracellularly but are so heavily walled that the lumen is almost occluded. Butler figures peg-like processes projecting from these hyphae into the cells, but apparently arrested by a cellulose cap. He distinguishes, as does Mangin, two layers in the sheath. He does not, however, identify callose and cellulose, but specifies that the inner layer belongs to the fungous hypha and the outer layer is deposited by the host cells 'in the effort to stop the fungal growth.'

Stämfli (1909) compares a rust-caused gall on *Rubus* with that reported by Guttenberg as due to the infection of the Alpine rose by *Exoascus Rhododendri*. In the latter the mycelium is limited to the first and second subepidermal layers, and the haustoria are sheathed with cellulose. The *Rubus* gall is completely penetrated with mycelium and the haustoria are without 'zellulose Kappe.'

Tischler (1911) describes cellulose sheaths around the older haustoria of *Uromyces Pisi* in the rhizomes of *Euphorbia cyparissias*.

Němec (1911) states that in tissue infected by *Uromyces Betae* the host plant many times covers the haustorium with a sheath while at other times the haustoria remain naked.

Higgins (1914) reports that the haustoria of *Cylindrosporium Padi* are enclosed by a sheath.

Colley (1918) regards the cellulose sheath of the haustorium of *Cronartium ribicola* on *Pinus Strobus* as an accompaniment of maturity or old age. The sheath forms a long cup-like holder at the base of the haustorium and a thick cap over the tip, while over the middle region it is very thin. Colley explains this peculiarity as the result of response by the host to two chief points of irritation: the point in the cell wall through which the haustorium entered, and the point of contact of the advancing haustorial tip with the host cytoplasm. Colley states that the haustoria of the mycelium in *Ribes* are not sheathed, that they are smaller and proportionately less frequent, on a less crowded mycelium.

Arnaud (1918) does not mention sheath formation in his studies on the Asterineae, but he shows such a structure in a few figures. In figures of the haustoria of *Meliola Andirae Puttemansii* and of *M. nidulans*, the slender penetrating neck is shown piercing the cuticle and the characteristic ampulla is encased in the indented epidermal wall. In the figure of the haustoria of *M. polytricha* forma *Anacardiaceae*, the filament has passed between epidermal cells to the palisade layer and the ampulla is encased in the wall of a palisade cell.

Weston (1920) reports sheathed haustoria for the two species of downy mildew which he has investigated in the Philippines, *Sclerospora philippinensis* and *S. spontanea*.

Thurston (1923) reports a noticeable sheath about the haustorium of *Gymnosporangium bermudianum*.

Allen (1923) describes a glistening, transparent sheath around dead haustoria of *Puccinia graminis Tritici*, form 3, on Mindum wheat. She concludes:

> It seems probable that the sheath originates from host cytoplasm, although the possibility is not excluded that the haustorium itself contributes to it by secretions of some sort, or that host, or fungus, or both, secrete more or less of cell wall substances around the haustorium.

Moss (1926), reporting upon fourteen species of Pucciniastreae, finds in most of the species disorganized haustoria enclosed in sheaths, which in staining properties resemble the cellulose of the host cell-wall. He thinks the sheath is laid down by the host cytoplasm in response to the stimulatory action of the haustorium. In *Milesina marginalis* and *M. polypodophila* he finds frequently a basal collar, which he considers an early stage in the development of the sheath.

Metabolic relations between host cells and haustoria. It is generally assumed that the rust works harm to its host by its increasing demands upon the food and water supply. Results which in other cases are often ascribed to toxic products are, with the rusts, commonly assumed to be merely culminating effects of inanition. Ward (1890) in his Croonian lecture points to the Uredineae as proof of the statement, 'In all cases where haustoria are developed, the mycelium enters into a peculiar symbiotic connection with the cells, and for some time merely taxes them as it were, rather than injures them directly.' Fromme (1913) suggests that the rust fungus 'is dependent on the transition products in photosynthesis.' Mains (1917) concludes from tests with *Puccinia coronata* and *P. Sorghi* that 'the rust is dependent upon the food supply of the host, and does not live upon its protoplasm.'

Reports of food disappearance in the region of haustoria as given in the literature support these statements. Butler (1907) reports in the case of *Sclerospora graminicola* that starch is absent in cells with haustoria even before the assimilatory activity at the time of spore formation, when the cells of the host collapse and die. Reed and Crabill (1915) ascribe to the presence of haustoria the disappearance of starch in the cells of cedar-apple tissue. The comparative studies of Mains (1917) upon stages in the development of *Puccinia Sorghi* demonstrate inanition as the outstanding effect of the rust upon its host. He gives specific data upon food disappearance from the host cells over a period extending from the third day after inoculation, when the mycelium was well developed, through the sixth day, when the first pustules appeared. The only abnormal effect which he observes in the host cell is a decrease of the storage starch in the parenchyma sheaths of the vascular bundles. During the drain incident to spore formation he finds the sheath cells in the vicinity of the pustules entirely devoid of starch. 'Yet even at this time,' he observes, 'the cells of the host do not show an injury such as one would expect if the protoplasm itself was attacked vigorously by the fungus.' This inanition effect on the corn is the more striking because, as Mains reports, the sheath cells at the time of their depletion are not invaded by haustoria. He concludes: 'It would appear that this loss of starch is due, not to a withdrawal of starch from the parenchyma sheath by the fungus itself, but to the utilization by the fungus of the material formed in the neighboring region before it reaches the parenchyma sheaths.' Mains notes also a disturbance in the normal water currents. He refers to the statement of Sachs that loss of water from dead tissue is much greater than from living. He thinks that such evaporation from dead areas developed around green infection centers causes a drain of water from these centers, which effects their ultimate death. This matter of evaporation from dead tissues may have bearings upon transpiration data.

It is difficult to get evidence upon the presence of soluble carbohydrates. Tischler (1911) infers from their high osmotic pressure, determined by plasmolysis, the presence of high sugar content in the vacuoles of infected cells of *Euphorbia Cyparissias*. Long (1919), by applying the Fehling test to extractions of digested leaf contents, has made a series of extensive comparisons of photosynthetic activity in plants under various conditions. Among these she made tests upon seedling oats and wheat infected with *Puccinia coronata* and *P. graminis*, respectively, and upon plants of *Arisaema triphyllum* naturally infected with *Uromyces Caladii*. She concludes that the fungus interferes seriously with the accumulation of carbohydrates by the host, and that sporulation reduces by more than 50 per cent the ability of the host tissues to make carbohydrates. She refers these effects to a possible interference with the transpiration of the host and to the drain of food by the fungus.

On the other hand, an accumulation of food in infected tissue is a well known phenomenon, and may be considered a stimulation effect by haustoria. Barclay (1886) has described swellings occurring upon the Himalayan *Urtica parviflora* infected by *Aecidium Urticae.* These swellings contain an abundance of nutritive material, which the hill natives eat with relish. Under microscopic observation Barclay finds granules both in the hypertrophied cortical parenchyma cells and in the central pith cells. He gives their blue reaction to Schultze's fluid as proof of their starchy nature although they show neither striae nor hila. He states also that they are readily soluble in water, for he misses them in water-mounted sections, but finds them abundantly in glycerine mounts. Barclay concludes that this fungus requires considerable aid from its host for its complete development, as the aecidia are developed only after the reserve food has been amassed. Barclay proved the heteroecism of this rust by infecting nettles with teleutospores from *Carex setigera*, but here again he finds evidence of the unusually heavy demands of the parasite, since seedling nettles were not successfully infected. They were unable, he states, to nourish a parasite that demanded so much. There was no accumulation in the *Carex* generation of the granules mentioned above. Halsted (1898) demonstrated starch in *Podophyllum* leaves infected with *Puccinia Podophylli* by soaking the tissue in iodine. He found the infection areas in the leaf definitely outlined by small veins, and starch was found only within these areas. Guttenberg (1905) gives several examples of storage. The abnormal pistillate clusters of *Alnus incana* infected by *Exoascus amentorum* contain a parenchyma rich in starch, which Guttenberg interprets as a nourishing tissue for the fungus. In *Capsella Bursa-pastoris* he finds evidence of sugar accumulation in the appearance of anthocyan, which precedes the formation of conidiophores. He states as further evidence of the development of a storage tissue that it is into these cells the fungus sends the characteristic small knob-like haustoria. Guttenberg finds still a third type of storage in *Rhododendron* infected by *Exobasidium Rhododendri.* The galls, he states, are water reservoirs. It has been already noted that Tischler (1911) infers high sugar content in cells of *Euphorbia Cyparissias* infected with *Uromyces Pisi*, because of the high osmotic pressure. The result is a thick leaf of xerophytic type.

The chloroplasts are pale and reduced in number. To this diversion of food into leaves which have lessened photosynthetic activity but increased activity in growth, Tischler lays the death or abortion of the vegetative points, which are not in themselves infected. Reed and Crabill (1905) report of the cedar-apples upon *Juniperus virginiana* that during summer, autumn, and early winter the fungus in the gall appears to stimulate the parenchyma of its host to prodigious activity in the multiplication of cells, and the storage of starch, which is used up during teleutospore production. Colley (1918) reports of *Pinus Strobus* infected by *Cronartium ribicola* that storage starch is usually present in excess, and that it is not completely used up by the fungus, as many grains remain in old dead cells after the cells are completely dried out. Colley suggests that excess starch is due to a lack of balance in physiological processes in the host cells—an unbalancing to which the fungus probably contributes, although other little understood environmental factors are known to lead to the production of excess starch in trees.

The observations quoted concerning abnormal accumulations of food have involved, in many cases, mention of hypertrophy and hyperplasy, which are responsible, even more than is food accumulation, for many characteristic deformations of host plants of the fungi. These structural effects of fungus stimulation upon the host occur with all degrees of complexity. The many slight modifications of host tissue, which have been detected by microscopic observation prove that these stimulations are more general than is at first realized. In the large number of cases in the literature which report hypertrophy and hyperplasy no special reference to the relation of haustoria has been mentioned. Their presence is reported in the gall as in any other infected tissue. The presence or absence of haustoria seems to have no bearing upon the meaning of hypertrophy and hyperplasy.

The physiological reaction of an invaded host cell involves translocation of foods, transpiration, and respiration, as well as photosynthesis. Comparatively little has been done to test the interrelation of these processes in rusted plants. Reed and Crabill (1915) have attempted such a study, using as material apple leaves infected with the aecidium of *Gymnosporangium Juniperi-virginianae*. They find, both by the measure of carbon dioxide consumed and by the carbohydrate cell-content, that the photosynthesis of diseased leaves is less than normal. They find that transpiration is not only lessened, but is a constant, instead of a fluctuating process. However, these transpiration effects, they state, are evidently due to blocking of substomatal cavities through hypertrophy of the host tissue. They find a temporarily increased rate of respiration and liken the action to a fever which wastes away the tissues of the victim. 'Parasitism,' they conclude, 'may be regarded as a type of injury.' This is borne out by their report of the poor growth and the unthrifty condition of the infected trees.

Increased respiration by rusted plants is reported by Nicolas (1920) from tests with *Puccinia*, *Melampsora*, and *Phragmidium*, as well as with *Urocystis* and *Taphrina*. His explanation agrees with that of Reed and Crabill in emphasizing great activity in the host. The fungus, he says, stimulates to hypertrophy and hyperplasy. The consequent inflow of a great quantity of hydrocarbons, indicated frequently by the abundance of anthocyan, realizes conditions favorable for a great increase of respiration. Increased transpiration at the same time tends to counterbalance the excessive turgescence. He reports the reverse in the case of ectophytes.

Decreased respiration is reported by Bailey and Gurjar (1920) for rusted wheat. Their test plants were cut two weeks before maturity. Both heavily rusted and sound specimens were sealed in glass tubes for respiration tests, and were later examined for moisture content. They conclude: 'If the respiration of these tissues is in any sense a measure of metabolic processes it appears that the metabolism was decidedly depressed in the rust infected plants.' They infer increased transpiration on the part of the rusted plants from the fact that their moisture content was much lower than that of sound plants.

Dodge (1923) finds in a case of *Rubus* infected with orange-rust a structural change in the host which might cause increased respiration and transpiration, although Dodge does not relate it primarily to these processes. He reports that when infection develops during the plastic period of leaf tissues, stomata develop over the infected areas in the upper epidermis, which ordinarily lacks them. This, Dodge believes, is a case of host action in the 'interests' of the fungus. The extra stomata develop only over areas infected by the gametophytic mycelium, and in these areas they develop before the appearance of the hypophyllous aecidial crust. Apparently then the new structures are not due to abortion of the normal stomata. Dodge concludes: 'The gametophytic mycelium of the rust stimulates the host to provide ready means of access by the sporophytic stage which is to follow later.'

Weiss (1924), after a review of literature dealing with the effect of parasitic infection on the water requirement of plants, concludes: 'Fungous infection may result either in acceleration or diminution of transpiration.' The cases of accelerated water loss are, he thinks, determined by injury to tissues or by the production of toxic excretions; the cases of diminution of transpiration are determined by alterations of the tissues in water absorbing and water excreting parts, by alteration of the osmotic relations of infected cells, and by the reduction of yield of tops and of grain coincident with an increased water requirement. He thinks, however, that increased transpiration is less likely to be the cause of the diminished yield than are destruction of chloroplasts in the infected tissue and the drain on the elaborated food reserves of the host.

These analyses of the causes underlying changes in respiration in infected leaves have not included a consideration of the fact that a part of the increased respiration must be the respiration of the parasitic mycelium. Judging by the gas exchanges which have been measured for various molds, this should be an appreciable amount. Weimer and Harter (1921) compared the relative amounts of carbon dioxide given off from two halves of the same sweet potato, one of which was infected with *Rhizopus Tritici*. It was found that the decayed half gave off a total of from 6.3 to 7.8 times as much carbon dioxide as the healthy half. The mass which respires in the case of the rust-infected tissue is host protoplasm plus parasite protoplasm, as against host protoplasm alone in an uninfected tissue.

The chloroplasts are perhaps the most delicate indicators of the degree of adjustment between host and parasite and the state of metabolism in the host-fungus complex. Destruction of chlorophyll is frequently found even in the case of the haustorial parasites.

A chlorosis which causes white-streaked leaves is a characteristic effect of the Sclerosporas upon maize as described by Butler

(1907), and by Weston (1920). Osner (1916) reports of Timothy smut that the mesophyll cells around the young sorus have lost their chlorophyll contents.

There are also reports of plastid disorganization due to rust infection. In some cases the yellowing may be secondary to hypertrophy. Thus DeBary (1853) reports a disappearance of chlorophyll in tissue infected by *Roestelia cancellata*. Reed and Crabill (1915) report of infection by *Gymnosporangium Juniperi-virginianae* that the palisade cells in the rust lesions contain carotin and erythrophyll but no chlorophyll.

The following seem to be cases where the tissue loses chlorophyll without hypertrophy. Ward (1882) describes as the sign of infection by *Hemileia vastatrix* the appearance of yellow spots, which spread centrifugally and darken to a dead black area. Richards (1896) reports that in cases of infection by *Aecidium houstoniatum* the chlorophyll is mainly disorganized by the fungus. Galloway (1896) reports in the case of infection by *Coleosporium Pini* that the chlorophyll bodies disappear and many large oil bodies are seen in their place. *Puccinia Asparagi*, as compared with other rusts, shows pronounced virulence. R. E. Smith (1905) describes the destruction of the green host tissue by this rust. The chloroplasts, he states, shrivel, collapse, and clump into several masses in the center of the cell. Smith relates this effect to the action of the haustoria, which he figures as unconstricted stubby branches. His report of the reaction suggests the *Botrytis* type. They 'penetrate the cell only slightly, if at all, and immediately the chloroplasts begin to react. . . . Apparently, a soluble substance, poisonous or enzymatic, is excreted to bring about this effect.' As noted above, Tischler (1911) reports of leaves of *Euphorbia Cyparissias* infected with *Uromyces Pisi* that the chloroplasts are pale and reduced in number. Reynolds (1912) reports in the case of infection by *Puccinia Potentillae* that the chlorophyll seems to have largely disappeared from the cells which are within the influence of the rust. Bell (1924) reports that fir needles infected with *Peridermium pycnogrande* turn pale green; those infected with *Peridermium balsameum* are blanched.

Disorganization of chloroplasts is also reported as one of the characteristic effects in rust-infected cells of more or less resistant hosts. It may be in these cases the outward sign of a hypersensitiveness, which, according to Stakman, underlies immunity.

Ward (1904) found distinct differences in the susceptibility of various brome grasses to *Uredo dispersa*. Over against his description of lack of reaction in a cell of a susceptible host, he describes for rust-resistant grass the appearance of pale flecks due to destruction of chlorophyll in the attacked cells, and in extreme cases the blackening and shrivelling of the infected spots, due to actual death of the cells. Marryat (1907), comparing the effects of *Puccinia glumarum* upon the susceptible Michigan Bronze and two more or less resistant wheats, American Club and Einkhorn, reports much the same results. Stakman (1915) writes of the action in cells of oats inoculated with a form of *Puccinia graminis* which does not grow in it normally:

> Within a short time after the hyphae become closely appressed to the host-plant cells, there are usually unmistakable evidences of some deleterious influence upon the host cells. The chloroplasts very often seem to be affected first. They may appear slightly corroded at first and somewhat irregular in outline, they may retain their identity for some time, but more often seem to be clumped together in more or less irregular masses . . . eventually the outlines of the plastids become obliterated almost entirely, leaving only a fairly homogeneous, uniformly staining, non-granular mass with little remaining semblance of structure.

Allen (1923) writes of an infected cell in the resistant Kanred wheat: 'The disordered contents of this cell, the absence of the nucleus, the clumped misshapen plastids, and the rough jagged points on the cell left by the irregularly collapsing wall give ample proof of the attack.' Of plastid reactions to rust in the cells of resistant Khapli emmer she writes (1926): 'The plastids are still discernible and are but little reduced in size, but both in their shape and staining reaction there is evidence of dissolution.'

In contrast to these reports of disorganization in rust infected tissue there are many reports of infection by rusts in susceptible hosts without obvious and immediate pathogenic reactions on the part of the host. Ward (1904) emphasized such a condition for the brome grasses susceptible to *Uredo dispersa:*

> One of the most surprising features of invaded cells is the longevity of their cell contents. Even in preparations of tissue thoroughly infested for some days—the nucleus, chlorophyll corpuscles, and cytoplasm may retain their form, color, and even their normal capacity for staining.

Evans (1907) in his many figures of rust-infected tissue of the cereals shows the chloroplasts in apparently normal position along the periphery of the cell, no matter what the age of the haustorium. Guttenberg (1911) figures plastids in a rust-infected cell of *Adoxa* lying in the primordial utricle and in the invaginated cytoplasm around the haustorium. Reynolds (1912) states that the chloroplasts of *Viola cucullata*, attacked by *Puccinia Violae*, are little affected. Klebahn (1912) makes the rusts the types for his group of strict parasites which do not cause discolored dead flecks as a sign of infection. Stakman (1915) writes:

> It is probably superfluous to call attention to the fact that when normal infection, such as occurs for example, when oats are inoculated with *Puccinia graminis* from *Dactylis glomerata*, takes place, the host cells remain at least apparently normal for a considerable length of time . . . The hyphae may grow very vigorously, send haustoria into the cell and branch profusely without destroying the chloroplasts or in other ways injuring the cell. Even after pustule formation has begun many of the cells just at the edge of the pustule, where the hyphae are massed in great numbers still retain their chloroplasts . . . .

Doran (1921) states of rust infected *Antirrhinum* that the chloroplasts fade slightly, but the yellow of the leaf fleck is due rather to color in the masses of mycelium. Allen (1923) describes a six-day-old cell of early Baart infected by *Puccinia graminis Tritici* as follows:

> The cell drawn contains two large haustoria, which are intimately associated with the living contents of the host cell, being covered with a rich layer of host cytoplasm. The infected host cell presents a flourishing appearance and may even have more plastids and cytoplasm than an uninfected cell.

When unaltered chloroplasts remain in infected areas in the midst of dying, uninfected tissue, the phenomenon may indicate not merely mutualistic adaptation but host cell stimulation by the fungus. This persistence of chlorophyll in infected regions, causing in Stakman's phrase 'green islands in yellowing tissue,' has been frequently noted, not only among the rusts but in other fungi. I have found the following instances mentioned in the literature.

UREDINEAE: Figures of *Puccinia coronata* on Avena, and of *P. dispersa* on *Secale*, Eriksson and Henning (1896); *Coleosporium Pini* on *Pinus virginiana*, Galloway (1896); *Cronartium asclepiadeum* on *Vincetoxicum*, and *Gymnosporangium clavariaeforme* on quince, Tubeuf (1897); figure of *Puccinia rubigo-vera Secalis* on rye seedling, Carleton (1899); *Uredo dispersa* on brome grasses, Ward (1902); Uredineae, Arthur (1903); *Uromyces Veratri*, on *Veratrum album*, Morgenthaler (1910); *Puccinia graminis Secalis* on rye, Stakman (1914); *Puccinia Sorghi* on corn, Mains (1917); *Uromyces appendiculatus* on partially resistant bean leaves, Fromme and Wingard (1919); *Puccinia graminis* on wheat, Long (1919); *Puccinia graminis Tritici* on Khapli emmer, a resistant wheat, Allen (1926).

ASCOMYCETES: *Uncinula Aceris* on *Acer platanoides*, and *Rhytisma punctatum* on *Acer spicatum*, Tubeuf (1897); *Venturia inequalis* on apple, Butler (1918); *Rhytisma punctatum* on Acer *pennsylvanicum* and *A. spicatum*, Overholts (1926).

CHYTRIDIACEAE: *Physoderma Zeae-Maydis* on *Zea Mays*, Tisdale (1919);

FUNGI IMPERFECTI: *Septoria Apii* on celery, Thomas (1921).

Immunity

An early and still prevalent conception of individual as contrasted to racial immunity associates it with the health and general vigor of the host. Raines (1922) has reviewed the history of this theory and set forth evidence for a counter claim, from the literature, and from his own experiments. His review covers field observations and culture experiments dealing with host nutrition, water relations, temperature relations, stimulants and depressants, trauma, age and maturity of host tissue. He cites the following authorities in support of the concept that in the rust diseases of the higher plants there is a tendency for the parasite to exhibit a higher incidence of infection and greater virulence on the host of greater vegetative vigor: 1883, Little; 1889, Bolley; 1902, 1905, Ward; 1903, 1905, Sheldon; 1903, Galloway; 1903, Arthur; 1904, Gibson; 1905, Christman; 1905, Smith; 1906, Butler and Hayman; 1907, Jost; 1911, Freeman and Johnson; 1912, Peacock; 1912, Biffen; 1912, Johnson; 1912, Voelcker; 1913, Spinks; 1913, Fromme; 1913, Zavitz; 1914, Eriksson and Hammarlind; 1914, 1917, 1919, Stakman; 1915, Hecke; 1917, Mains; 1917, Stakman and Piemeisel; 1918, Butler; 1918, Giddings; 1919, Stakman and Levine; 1919, Lauritzen; 1920, Bailey.

The instance which Raines cites from R. E. Smith's report (1905) upon asparagus rust states that the very quick-growing succulent asparagus which grows upon a peat soil in California lacks resistance to injury and succumbs readily to rust. This may, from the standpoint of luxuriant growth, be interpreted as susceptibility in a vigorous host, but in an earlier article Smith (1904) gives the opposite interpretation for asparagus, stating that an abundance of soil moisture during the summer has a marked effect in retarding the development of rust by giving the host greater vigor and resistance.

I can add to the list of Raines the names of the following men who link the health of the host plant with susceptibility: 1912, Klebahn; 1918, Clinton; 1924, Stakman and Aamodt; 1926, Hart.

The findings of Dickson (1923) for *Gibberella Saubinetii* in seedlings of corn and wheat furnish indirect evidence along the same line, for although they report that the seedlings blight most at temperatures which are different from those of optimum growing conditions for corn and wheat, they claim that susceptibility is not due to ill health of the host, but that the temperatures unfavorable to host growth merely prolong the period during which the seedling sheath is susceptible to penetration by the fungus.

The establishment of the fact that to the obligate parasite host vigor furthers infection brings a new viewpoint in considering the fundamental question as to the nature of immunity. According to Hursh (1924), in his historical review of the subject of rust resistance, the early investigators, Sappin-Trouffy, Cobb, Peterman, and Farrer, saw in protective leaf surfaces, resistant tissues, stomatal characters, and leaf positions a basis for resistance. Eriksson and Henning (1896), Ward (1902), and Biffen (1907) threw the emphasis upon physiological characters as the basis for resistance.

The investigations of Allen (1923) upon wheat rust give serious attention again to the possibility of morphological causes of resistance. She thinks that for Kanred, the resistant wheat studied, 'true immunity' is a physiological character; but she finds two morphological characters which favor resistance—stomata which shut out the majority of the fungi, and heavy contact walls adjoining pathological cells. Hursh (1924), in studies on the resistance of wheat to *Puccinia graminis Tritici*, has set forth data concerning morphological peculiarities of the host in the most detailed study along this line since that of Ward. He concludes: 'Resistance to stem rust must be considered as being due fundamentally to a complex physiological relationship.'

The problem of the nature of the physiological resistance of a host to rust was early approached from the cytological side. Klebahn (1896) made from *Puccinia Digraphidis* Soppitt two biological species, *Puccinia Convallariae-Digraphidis* and *Puccinia Smilacearum-Digraphidis*, on the ground that the first found a susceptible host in *Convallaria* and the second in *Polygonatum multiflorum*. *Puccinia Convallariae-Digraphidis*, in leaves of the wrong host, *Polygonatum multiflorum*, caused red-brown flecks. Microscopic examination proved that in every such spot sporidia had bored through the walls of epidermal cells, and the germ tube had swollen into an intracellular sac, but, Klebahn states, the fungus was not in a condition in the epidermal cell to develop itself into mycelium in the interior of the plant. Antagonism between the fungus and the host led here, on one side to a killing of the attacked cell, and on the other to a checking of development of the parasite. The work of Ward (1902, 1905) upon *Uredo dispersa* and *Puccinia glumarum*, confirmed by Gibson (1904) upon chrysanthemum rusts, and by Marryat (1907) upon *Puccinia glumarum*, definitely located the infection reaction for rusts as one between the host protoplast and the penetrating haustorium.

This is confirmed from another group of highly adapted haustorial parasites. Salmon (1905) described an experiment with *Erysiphe graminis* to ascertain at what stage and in what manner the action of the 'wrong' host plant stopped the further growth of germinating conidia. Conidia from wheat were used for inoculations upon barley. There were no true infections, but microscopic examination 24 hours after inoculation showed that germ tubes and appressoria had been produced by nearly all the conidia, and that in the majority of cases a penetrating tube had entered an epidermal cell and had formed an incipient haustorium in the cell. This small rounded body, however, was in striking contrast to the normal lobed haustorium of *Erysiphe graminis*, and by the fifth day most of these rudimentary haustoria were completely disorganized. Salmon (1905) made similar tests with the mildews of brome grass, wheat, barley, and oats, and finds that the parasite is hindered by influences of the 'wrong host' from carrying on its normal functions and thus obtaining the food necessary for the production of mycelium. He concludes that 'susceptibility or immunity, at all events in the case of these host-plants and their "biologic forms" . . . depends on the capacity or incapacity for maintaining certain working relations between the haustorium and the host-cell.'

The segregation of biologic species of *Puccinia graminis Tritici* has offered most favorable material for cytological studies of resistance. Stakman (1914) figured results of the struggle of *P. graminis Tritici* in the resistant tissue of Khapli wheat.

Allen (1923) compared reactions of *P. graminis Tritici* in susceptible Baart, and resistant Kanred wheat. Her cytological studies confirm observations of earlier workers, in that she indicates the host cell as the place where resistance is expressed, and the attempted penetration of a haustorium as the act by which resistance is stimulated. Her observations are further elaborated in a series of comparative studies upon several forms of *Puccinia graminis Tritici* in resistant wheat (Allen, 1923, 1926). Hart (1926) finds physiologic specialization in the case of *Melampsora Lini.* She reports that Argentine flax apparently possesses 'a true physiologic resistance. . . . Argentine is hypersensitive to the pathogene, which kills some of the host cells quickly and is then unable to develop further.'

Such observations and descriptions lead of course to the question of the nature of the resistance thus located. The differential mineral culture experiments of Ward (1901), although somewhat indeterminate in result, indicate that resistance is not a matter of nutrition, and after his study of the rusted brome tissues (1905) he concludes in terms of current pathological theory that

> Infection and resistance to infection depend on the power of the fungus-protoplasm to overcome the resistance of the cells of the host by means of enzymes or toxins, and reciprocally, on that of the protoplasm of the cells of the host to form anti-bodies which destroy such enzymes or toxins, or to excrete chemotactic substances which repel or attract the fungus-protoplasm.

Gibson (1904) gives Ward's idea in the statement:

> The facts seem to suggest that the death of the entering hyphae is not due so much to starvation as to some poisonous substance emitted by the cells, for on examining an epidermis freshly stripped from a leaf inoculated three days before, the hyphae outside are seen to be alive and unshrunk while a great number of those inside are already dead and shrivelled.

Marryat (1907), also from Ward's laboratory, states:

> We are therefore forced to fall back upon the theory that immunity to disease is due in these cases to the production of certain toxins and anti-toxins by host or parasite or both, which are mutually destructive.

Stakman (1915), as noted above, has developed the conception of hypersensitiveness as the basis of immunity. He states the case as follows:

> The essential fact is that the fungus gains entrance in the same manner in susceptible and resistant forms, but acts differently thereafter. In susceptible forms it grows vigorously without seriously affecting the host cells

for some time. In resistant forms, on the other hand, a very rapid action results in the almost immediate death of the host cells. The degree of susceptibility is indicated to a certain extent by the rapidity of this action The more resistant a form, the quicker are a few host cells in the immediate neighborhood of the invading hyphae killed and the sooner does the fungus itself cease activity.

Allen (1923) concludes from her work upon Kanred wheat:

> The observations recorded here are in line with the theory that immunity is due to definite antagonistic chemical interactions between host and parasite.

The history of attempts to correlate the immunity of a given host with the physicochemical properties of its cell sap is reviewed by Hursh (1924). Such studies extend from those of Comes (1909) to the experiments of Hursh himself upon determination of the depression of the freezing point, total solids, average molecular weights, hydrogen-ion concentration, and sugar content of wheat varieties. He concludes:

> There are differences in the physicochemical properties of the sap of different varieties of wheat. It has been impossible, however, to make definite correlation between these properties and rust resistance.

This is disappointing in view of Stakman's earlier conclusion (1914) that the question as to the immediate instruments of immunity can probably be answered only by means of biochemical investigations. Possibly Hursh did not study the right properties. In the studies of Allen (1926) upon three forms of *Puccinia graminis Tritici* in resistant Khapli emmer, the conclusions, drawn from the cytological data, all point to chemical secretions as the means by which both organisms cause toxic effects, and as the probable cause of the recovery which occurs in cell groups infected by the less resisted forms. For example she writes:

> Perhaps, on the other hand, the secretions of the young fungus set up counter-reactions in the host, by means of which later secretion of the same substance is rendered less destructive.

INVESTIGATIONS: THE HAUSTORIA OF THE UREDINEAE

Puccinia Sorghi Schweinitz

External phenomena of infection

For a study of host-parasite relations in the Uredineae, *Puccinia Sorghi* was chosen because of the ease with which the rust can be grown upon *Zea Mays* throughout the year under greenhouse conditions. Golden Bantam corn proved a susceptible host, but it did not flourish as well as field corn under plant house conditions. Flint corn was therefore used for the following experiments. It was a susceptible host and grew readily in the plant house. No attempt was made to determine physiologic species. Although for specific tests many inoculations were made by spraying, a progressive supply of material was assured merely by setting successive pots of corn seedlings near rusted corn plants. Cultures were under observation in the Columbia University plant house from 1921 to 1923.

Germination studies of corn rust were made by applying a spore suspension to a leaf surface and insuring a continued moist atmosphere by clamping a watch crystal over the surface. Three days after inoculation the epidermis was stripped off and mounted in lacto-phenol and Coton Bleu. The fungus stained a deep blue and thus the germ tubes could be traced readily upon the epidermis. Camera lucida drawings were made from the preparations. In such moist chamber growth the germ tubes are long and much branched, and run in all directions, as Weber (1922) has observed, without reference to the furrowed leaf surface. Weber reports, for the corn rust, stomatal entrances without, as well as with appressoria. According to my observations the lobed attachment disk over the stoma is typical (PLATE I, FIG. 1).

Infection in a vigorous host. The external phenomena of infection, as many times observed, are as follows: The first signs of infection visible to macroscopic observation are light green flecks in the green leaf. They are abundant five days after inoculation. Infections were successful with plants only one inch high with the leaves pushing out of the coleoptile. Attempts on several occasions to infect the coleoptile were unsuccessful. These attempts were not numerous enough to prove such infection impossible, but the rapid drying and early death of this tissue prevent any considerable development of the rust.

Pustules of uredospores are erumpent two or three days after the appearance of the flecks. These are soon surrounded by an oval border of secondary pustules at the circumference of the pale green spot. Later, in the case of vigorous infections, the sori become confluent in irregular patches which lie in yellowish or brownish areas in the green leaf. Teleutosori at their first appearance break the epidermis in the form of short clefts, as do the uredosori, and they are distinguished among the uredosori only by the black coloring against the brown. They lie frequently along a vein, where the lines of sori tend to become confluent. Thus in late stages black streaks an inch or more in length are common, or crusts of close-lying, parallel, linear sori are formed. In the mature host, these aggregations of teleutosori occur chiefly along the midrib of the leaf, on the leaf sheath, and on the stem, both within and below the sheath. These tissues are similar to one another in their prominent vascular development. In these regions internal sori often lie directly below the external lines. In an earlier study (1924) I called attention to these internal sori as a probable expression of excess reproductive activity. These reproductive proliferations in a susceptible host are in contrast to an instance of an internal uredosorus reported by Allen (1926) for form 9 of *Puccinia graminis Tritici* on the resistant Khapli emmer. She interprets the case as an ineffective effort of a dying fungus to break through the host tissues.

There are of course many references in the literature to the occurrence of anthocyan in the tissue of infected plants, but the relation to its occurrence in uninfected tissue has been little discussed. My own observations merely add to the list of observed occurrences.

The presence of anthocyan was frequently observed in connection with infected regions of mature corn plants, especially in winter. In cases of scattered sori on vigorous green leaves anthocyan was sometimes present in a sharply defined border about each sorus or small group of sori. The purplish borders were often one-eighth of an inch broad around the sori. The secondary infections often lay in this border. This development of anthocyan is possibly a winter effect. The color faded as the sori ripened, and in late stages there were fewer examples of the sharply outlined red ovals, although anthocyan was present along the edges of the leaves and the midribs. In one case both uredo- and teleutosori had appeared on the leaf sheaths and even on the husks of a young ear, and these sori lay in the midst of irregular blotches of anthocyan. In another case, four-month-old corn plants showed anthocyan bordering sori on the older leaves and the leaf sheaths. In the most heavily infected leaves anthocyan was evident along the midrib, but not around the sori.

The anthocyan was naturally most sharply outlined around isolated primary infections, yet it is by no means so constant a feature at this stage as in heavily infected older plants, where it is less certainly related to the presence of the fungus. In cases of field infection with corn rust, anthocyan, while abundant in leaves and stems, appeared to have little significant relation to the rust.

Infection under inhibiting conditions: the so-called green island phenomenon. As widely observed and reported in the literature, under certain conditions the chlorophyll seems to be more persistent in the neighborhood of rust sori and some other fungus infections.

I regard these green spots as areas of balanced adjustment between host and fungus, as shown from a series of rust cultures upon subnormal corn plants. The first experiments deal with effects of over crowding of the plants. Corn was planted in seven-inch pots, five to seven seeds in a pot. When the seedlings were four weeks old and each had two or three leaves, they were sprayed with uredospores, and were incubated in a cold moist chamber. Observations were made eight days later. The five-week-old plants ranged from twelve to twenty-four inches high, and in every case had developed two or three additional leaves since the inoculation a week before. The plants were crowded in the seven-inch pots. This crowding had caused early dying of the older host leaves and thus a chance was given, even at such an early stage of infection, to observe the effects of death of the host tissue on the infection phenomena. There was a marked similarity in the leaf conditions on all the plants. The coleoptile had become a withered scale. The first leaf was either dry and brown, or yellow with a dry tip. The second leaf showed a dying tip. The third leaf and the two or three new leaves were green. The leaves present at the time of inoculation were in every case rusted, but the sori were usually limited to the terminal, that is, the older, half of the leaf. The lowest leaf had evidently dried too rapidly to allow much development of rust. There were scattered sori on this dead leaf and they were uniformly green-bordered. The second leaf showed green-bordered sori in its yellowed tip. The third and fourth leaves showed the heaviest infection. These were the terminal, somewhat inrolled leaves at the time of inoculation. They may have been more favorable for inoculation because of their cornucopia-like form and hence their retention of moist air, but I believe their greater area and fresh condition were also favoring factors. The health of the leaf apparently favored the growth of the mycelium. The groups of sori on these fresh green leaves were surrounded by lighter green or by yellowish borders. The two upper leaves which had appeared since inoculation were in all cases uninfected.

Since all the sori on these plants at the time of observation (eight days after inoculation) were evidently the result of the single inoculation, we see here a definite variation in the behavior of the parasite, depending upon variations in condition of the leaves of the host. In the dying leaves the spread of the fungus is limited, but within the regions bordering the sori the death of the tissue is delayed, and the normal green appearance of the host tissue is long preserved, hence the phenomenon of 'green islands.' Just how the rust hyphae act to delay the death and drying out of the host tissue from which they are withdrawing both food and moisture is not at all clear. In fresh green leaves the clustered sori indicate a more extensive spread of the mycelium, and the bordering areas around the sori are paler in color as compared with the rest of the leaf.

The same contrast between infection in dying and in fresh tissue was often found within the limits of a single leaf, which showed 'green islands' on the dead or dying tip, and paler areas around the sori on the fresher, younger base of the leaf.

The effort to reproduce the colors in sketches of green-bordered sori leads me to think that the green appearing in the 'green islands' is as deep in color as in the normal leaf and does not appear green merely by contrast with adjacent yellow. If this is true, the spots must actually regain color, since they are deeper than the infection spot in the earlier, green leaf stage. Such a reaction indicates stimulation as well as preservative action by the fungus upon the dying host tissue. Allen (1926) thinks that this is what happens with the forms of *Puccinia graminis Tritici* which are able to effect some adjustment and live in a resistant host. She explains the pale fleck as due to a shrinking of the plastids, and the green spot as due to their subsequent enlargement. She finds the reversal chiefly at the borders of the infection spot, where the fungus in its advance effects apparently a better adjustment. She writes of form 27:

> When the hyphae in passing stop to form haustoria, the invaded cells often are stimulated, the cell contents become richer and the plastids larger . . . part or all of this outer zone regains a green color, and more rarely the central area also turns greener.

As I have noted in the review of literature, this is a phenomenon associated with degrees of resistance in the host, but Allen also notes the occurrence of 'green islands' under conditions that seem like those which I have described in the corn:

> When, as commonly happens, the infected leaf dies prematurely and the uninfected parts turn yellow, the areas occupied by mycelium still remain green and hold their chlorophyll more tenaciously than healthy tissues.

The same potbound conditions of corn were studied in a ten-inch pot of twenty plants which had become infected by standing near rusted stock. The plants had each developed six or seven leaves and rust sori were abundant. The contrast already noted between the lower dying leaves and the vigorous upper ones was apparent here. Under the potbound conditions, the lower two or three leaves on every plant were dead or dying. These showed green zones around the scattered sori as in the cases noted above. The upper leaves were still fairly vigorous. They showed heavy infection in all stages from flecks to abundant sori in light green areas. Later the heavily infected blotches became sere and dead, while the uninfected areas were green. Two plants in this pot had rotted at the base and their leaves were wilting at the time of the first observation. Here, as in the lower drying leaves of the other plants, the preservative action of the rust mycelium upon the host tissue was apparent. Even on the terminal leaves of these plants the areas around the sori stood out deep green in the wilted yellow-green leaf. The apparently mutualistic relations between host and parasite in the infected regions of these dying plants were in striking contrast to the progressive death of the host tissue as seen in other plants in the same pot, in areas of vigorous infection in a vigorous leaf. This retention of green in the rusted areas of a leaf dying from other causes was also strikingly shown in the case of a corn leaf which was kept in water in the laboratory for a week. When picked, the terminal half of the leaf was evenly green: a few groups of sori were just appearing and around these a faint yellow showed. Two days later the sori were more noticeable, and each sorus or group of sori was encircled by deep green while the general leaf tissue was paler. By transmitted light four color areas were distinguishable: (1) a narrow light green ring immediately around the sorus; (2) a deep green ring; (3) a light area surrounding and often linking several groups of sori; (4) an intermediate green of the general leaf tissue. This differentiation of color zones around the sorus, in particular the occurrence of the deep green zone (2), seems to confirm the belief of Allen that there is a regaining of green in the outer region of infection. Four days later the upper third of the leaf had become dry and brown with 'green islands' still showing around the sori. Below this dry tip was an area which had become water-soaked. Here the general leaf tissue was transparent and colorless, but the sori stood out in the center of distinct 'green islands.' Anthocyan had developed both above and below the water-soaked area.

The 'green island' condition is less frequent in corn grown in the greenhouse during the summer. The continued spread of the infection produces more extensive dry yellow areas, following and including the areas with the light green bordering. The withered leaf shows no trace of green.

The same contrast between yellowed tissue around sori on normal vigorous leaves and green tissue around sori on less vigorous leaves is found in rusted corn growing out of doors. In September, 1921, a field of rusted Golden Bantam corn was found in Lenoxdale, Massachusetts. The field covered half an acre, stretching north and south in about ten rows. The infected plants occupied a square across the middle of the field in a slight hollow of the rolling ground. The infection seemed to have followed here much the same course as that described for the greenhouse stock. The stages are figured on plates 8 and 9. The most abundant sori were noticeably on fresh vigorous leaves. Around these sori the border was, according to age of the infection, either pale green, or dry and yellow. Figure 65 shows pale green borders around the sori in an early stage of infection in a fresh green leaf. Figure 66 shows dry areas around the confluent sori of a late stage of heavy infection in a green leaf. These conditions were found on the upper half of all the rusted plants. The lower leaves were in various stages of dryness and on them 'green islands' were frequent, and persistent long after the leaves were quite dry. Evidently the normal progressive dying off of the lower leaves in this thickly planted field produced the same effect as that observed in the potbound greenhouse plants. Figure 67 shows the green-bordered sori in one of these dying leaves which is yellowing but still succulent. Figures 68 and 69 show the green bordered sori in nearly dry basal leaves. Figure 70 shows a few persistent 'green islands' in a dry, brown, basal leaf. This figure indicates also, by the small number of its sori, the check which the rapid drying of the basal leaves offers to the spread of infection. On these dry leaves the sori had frequently not broken the epidermis. This is perhaps another evidence that the growth of the parasite was checked by the weakening of the host. Corn in this field had made a fairly normal development, notwithstanding the rust. The ears were well-filled and apparently as abundant as in the unrusted part of the field. The host growth had generally outstripped that of the fungus, as the upper leaves were but slightly infected, and the leaves of the rather numerous axillary branches and the husks were seldom infected. The heaviest infections were usually on the fourth or fifth leaves from the top. Frequently the infection stopped abruptly here. One low plant whose top leaf was on a level with the third of the next plant was completely rusted, the second leaf from the top showing the most numerous sori.

An extreme case of heavy rust infection was found in October, 1923, in a field of Golden Bantam corn in Norton, Massachusetts. Practically every leaf on the plants was dusty with erumpent sori of both uredo- and teleutospores. The latter in particular made heavy crusts on leaf bases, leaf sheaths, and stems. Dehiscence of the sori on the inner surface was a frequent occurrence in the case of the leaf sheaths, and thus stem infection had resulted. The rust growth had kept pace with the growth of the host, extending even into husks and tassels. The dehiscence of the sori on the husks was often on their inner surfaces and by this means there had apparently resulted a progressive infection through several layers. Infection of the kernels was not observed. In the tassel both uredo- and teleutosori were abundant on each rachis and pedicel and on the walls of the anther sacs. Several plants showed smut galls as well as rust. The farmer reported the ears from this rusted corn abundant and of good quality, but said they had run small and were not evenly filled out. He had made three plantings at successive dates and all three had become infected. In this instance of excessive infection on vigorous host plants there was comparatively little expression of the 'green island' phenomenon. Instead, the borders around individual sori or around the blotches of confluent sori were usually dry and brown in the green leaves. Only on occasional dry basal leaves did the green spots show around sori. In these cases the conditions of the potbound plants were evidently repeated. Green spots were abundant on a branch above a basal leaf on a dry plant of the first planting. This shoot was evidently of later growth than the main plant and was dying from a rotted base. Here again, in the ill-health of the host the preservative action of the fungus appeared.

'Green island' formation was also observed in the greenhouse in the case of *Uromyces appendiculatus* on seedlings of Kentucky Wonder Bean, which had been inoculated when two weeks old with spores from infected bean pods. A month later the plants showed both uredo- and teleutosori. As in the corn, these were bordered with green on the dying older leaves. In this netted-veined leaf the infected spots are circular, while in the corn they are oval or oblong between the parallel veins. Secondary sori were formed at the circumference of the green area. In the dry leaf an outer border of more transparent tissue appeared around the green spot.

Cytological phenomena of infection

The haustorium and its relations to the host cell. Cytological studies of infected corn tissue were made from a variety of fixations. The solutions of Flemming, Bouin, Merkel, and Carnoy, and 50 per cent alcohol were used. Flemming's medium solution was the fixative most frequently used. Flemming's triple stain was most frequently used, but comparisons were made with Gram, Gram-Weigert, and Heidenhain's haematoxylin.

Plates 1 to 3 show the haustorium in its relations to the host cell in leaves whose stages represent the normal course of a vigorous infection. Figures 2 to 13, plate 1, are from leaves which showed merely the pale fleck, the first sign of infection. Spores lie on the surface of the leaf and germ tubes are visible. Substomatal vesicles occur, whose proliferations reach the opposite epidermis. Young haustoria are abundant in both mesophyll and epidermal cells. The haustoria arise usually from a densely filled, terminal, hyphal cell, which appresses itself to the host cell wall (FIG. 2). Sometimes this haustorium mother cell is a branch from a terminal cell (FIG. 10). Occasionally it is the penultimate, instead of the terminal cell (FIG. 9). Its paired nuclei are usually clearly marked (FIG. 11).

Parenchymatous cells of the type commonly attacked by the haustoria of rusts are in general turgid vesicles bounded by a wall and plasma membrane, and with a large central vacuole filled with a sap, whose osmotic relations with its environment are commonly assumed to determine the turgidity of the cell. I shall use the old term primordial utricle for the peripheral layer of the protoplast, including both plasma membrane and tonoplast. The question whether the penetration of such a cell by a fungous hypha or a haustorium involves the puncturing of this primordial utricle with release of the cell sap, or merely its invagination, has been raised by many students of host-parasite relations.

The corn rust haustorium plainly pushes in the primordial utricle rather than pierces it. This fact is particularly evident in these early stages. There is no apparent thickening or alteration in the host cell wall at the place of contact, and no invagination of the wall. The penetrating filament arises as a mere papilla, and develops as what appears like a very slender rod of densely staining homogeneous substance. There is a clear area between this minute peg and the primordial utricle (FIGS. 3, 4a). This appears also around the dark spherical tip shown in figures 5 and 6, and around the lobed tip of figure 7. Apparently this area later becomes the digestion cavity, which may be seen more or less clearly around lobes of the haustoria.

The characteristic lobing of the haustorium commences while the contents, with the methods used, still stain as an undifferentiated mass. Most frequently the terminal knob becomes irregular and forms two or more lobes, each of which in the mature form has one or more nuclei. Figures 7 to 12 illustrate the lobing. Occasionally the branching commences midway on the filament, leaving the stalked knob as the central branch (FIGS. 8, 12). Occasionally one finds an unbranched haustorium which has enlarged into a nucleate vesicle. The lobed haustoria must develop rather rapidly, as mature forms are not infrequent in this flecked leaf material. Figure 13 shows the characteristic short, slender stalk and digitate lobes of the mature haustorium. The dense cytoplasmic contents and the well defined nuclei indicate activity of some kind in the haustorium. It is perhaps significant that the nuclei lie in the larger lobe, which indents the host cell nucleus. The fungous cytoplasm is especially dense at the tip of this lobe. There are frequent contacts, in this material, between haustorium and host cell nucleus, but they occur usually with the more advanced haustoria. I did not observe cases where the host cell nucleus lay at the point of penetration. Both fungus and host cells appear to be in healthy condition. Chloroplasts in the primordial utricle are of the same size as in uninfected cells. The host cell nucleus is of normal size and shows a delicate reticulum.

Figures 14 to 18, plate 2, show slightly older stages of the rust, from a leaf which showed young sori surrounded by pale green in a green leaf. Within these spots the fixed material shows that the mycelium crowds all the intercellular spaces. Practically every mesophyll cell and many epidermal cells are penetrated by haustoria. The short-stalked, digitately lobed haustorium is seen here in great variety. The two-lobed form is at first sight most common, but it often proves to have other lobes lying in a different optical plane. The three-lobed haustorium shown in figure 16 is in reality five-lobed, and the one shown in figure 18 is four-lobed. A single, auricled sac is frequent in epidermal cells (FIG. 17).

In the stalks of these haustoria, as compared with those from the flecked leaves, one finds a development which may, I think, serve as an index of a change in the host-parasite relation. Figure 15 shows one haustorium with a filiform stalk such as has already been described as typical of the mature form. The second haustorium in the cell shows a conspicuous thickening half way up the stalk. Figure 14 shows a slight thickening on the stalk. Figure 18 shows a more decided basal ring. Throughout the sections of this material, along with many slender-stalked haustoria, there are many variations of a broad or narrow ring-like zone about the stalk. It is not at all clear whether this thickening arises as a differentiation of the outer surface of the haustorial wall or as a deposit from the host cytoplasm. Its position on the stalk, however, frequently coincides with a layer of host cytoplasm (FIG. 14).

In both the haustoria of figure 14 a thin wall is distinguishable within the so-called digestion vacuole. In this, as well as in the case of other lobed haustoria figured later, the clear enclosing area cannot be traced completely around the lobes, but its occurrence indicates digestive activity on the part of the haustorium, and offers evidence for invagination of the host cytoplasm. Figure 14 shows a rare case of a host nucleus appressed against the base of the haustorial lobes. Allen (1926) finds such a position a frequent occurrence in rusted Khapli emmer, and sees in it a host-nuclear offensive on the part of this resistant wheat.

Figures 19 and 20, plate 2, and figures 24 to 31, plate 3, show conditions in later stages of the corn rust, when erumpent pustules lie in yellowed areas in a green leaf. The material from which figures 19, 20, and 24 to 29 were taken was fixed in Flemming's stronger solution. Possibly on this account the host cells show evidences of disorganization. Note the possible excretion products and the plasmolysis in the cell of figure 19; note also the clumping and shrinking of plastids and disorganization of host cell nucleus in figure 24. The sections were cut longitudinally. In figures 24 and 25 a crowded mycelium is noticeable in the intercellular spaces which make re-entrant angles into the lobed mesophyll cells. Haustoria frequently arise from these intrusions and extend parallel to the long axis of the cell (FIG. 25). Figures 19 and 26 show clear-cut digestion vacuoles.

The series was chosen to show variations in the haustorial thickenings. Some degree of thickening is characteristic of practically all haustoria in this material. They stain regularly like the thickenings of the host walls. They are most often deep blue or purple with the triple stain, but in some cases they take an excess of orange-G. In the median optical section of figure 19 the protein core of the haustorium shows within the thickened stalk; in figure 20 the contours of the heavy wall of the haustorium suggest lobes within the sheath. The basal socket (FIGS. 25, 26) is so conspicuous in this material that it often serves to locate haustoria whose lobes extend into a different plane. The stalked cup is at times found broken off in the cell, and may lie so that the lumen of the haustorial tube shows as a circular opening. Very commonly the thickening forms a cup at the base of the lobes of the haustorium instead of around the stalk (FIGS. 24, 27). Figures 28 and 29 show a condition, frequent in epidermal cells, of haustoria which fail to develop the normal stalked form, and become completely encased. Figure 28 shows projections of host cytoplasm around the knob-shaped mass. Figure 29 shows an invaginated plasma membrane of the host cell. The conjugate nuclei within the heavy wall in figure 29 indicate that the haustorium was still alive. These epidermal cells are, I think, the last to be invaded, since the hyphal branches from the substomatal vesicle spread more rapidly through the mesophyll. Possibly the fungus is by this time less vigorous; possibly the greater thickness of epidermal cell walls is correlated with sheath formation. The heaviest sheathing is in general found where a haustorium has entered a thick-walled cell. Thus the cells immediately under a sorus are most apt to contain heavily sheathed haustoria. Allen (1926) thinks that the epidermal cells of Khapli emmer differ chemically from the rest of the leaf. In this resistant wheat, however, the reaction which she reports is the reverse of what I have found in corn, where the epidermal cells show less resistance to rust.

Figures 30 and 31 are cross sections from different leaves which were, however, at the same infection stage as the rest of those shown in plate 3. In figure 30 thickenings have developed on the stalks of both haustoria. In figure 31 the haustorial lobes not only issue from a lobed socket, but are apparently thick-walled over their whole extent, as they stain deep orange; nuclei are discernible in the lobes; an hypertrophied host cell nucleus overlies the lobes. This haustorium seems a massive development in contrast to a second one in the cell. This second one is a slender-stalked, lobed form, typical of earlier stages of the rust. Its walls are evidently thin, as the purple of the protoplasmic contents is its dominant color.

I found evidence of an interrelation between sheathing of haustoria and a heavy drain upon the host incident to a heavy infection, in material from the rusted Golden Bantam corn from Norton, whose extreme infection I have already described. Many of the leaves from these plants were covered on both sides with sori, and there were many instances of internal sori. These cases of internal sori furnish additional data in support of my conclusion (1924) that the phenomenon of internal sori is due to excessive reproductive activity.

Figures 32 to 34, plate 3, show cells from a heavily infected leaf sheath of this corn. The sori lay in yellow areas in a green leaf. Sori of teleutospores are confluent on both surfaces and between these the leaf is double the normal width by reason of crowded cysts of internal sori. In addition to the intracellular sori the intercellular hyphal masses form a pseudoparenchyma. The hyphae are poor in contents and stain deep orange, making a striking contrast to the purple or blue of the thick host cell walls. Both the orange-stained host cytoplasm and the red-stained nuclei show disorganization, but this may be due in part to heavy frosts, which occurred before I gathered the leaves. The haustoria in this tissue all show some degree of sheathing. The sheaths are exceptionally heavy in the thick-walled cells in the vicinity of sori. The haustorial thickenings show the same staining reaction and the same layered effect as the host cell walls. Figures 32 and 33 show haustorial lobes issuing from heavy basal sockets. Figure 34, from a tangential section, shows the contrast between the thinner walls and less developed sheaths at a distance from a sorus, and the thick walls and thick sheaths near a sorus.

A further suggestion of a correlation between haustorial thickening and the virulence of the fungus is indicated in a series of sections of leaf sheaths and of stem and cob tissues from infected corn grown in the greenhouse, which contrast the conditions around uredosori in green tissue with those around teleutosori in yellowing tissue. Figures 35 to 37, plate 4, are from uredo material; figures 38 to 40 are from teleuto material. Cells in the region of the young uredosori show abundant mature haustoria. They are many-lobed, and usually in close contact with the host nucleus. The plastids are frequently clumped around nucleus and haustoria. The nucleus is often hypertrophied, as may be seen by comparison of figure 35, an infected cell, with figure 36, an uninfected cell. With all this evidence of abnormal conditions due to the presence of the parasite, the haustoria in this fresh green tissue are uniformly slender-stalked. Figure 37, from the tissue of a young corn cob which was artificially infected, shows an exception. This thick-walled cell was isolated by hyphae of a sorus. The walls of host cell and of haustorium are shaded in the figure. In general, throughout the soft thin-walled parenchyma of the cob the slender-stalked form of haustorium prevails. Haustorial sheaths occur in connection with the heavier demands incident to teleutospore production. Figure 39 is from heavily infected tissue of a leaf sheath below a teleutosorus. There is extreme hypertrophy of both host cell and host nucleus. The haustorium issues from a well defined basal socket and indents the nucleus in the midst of a tangled mass of cytoplasm, plastids, and haustorial lobes. Figures 38 and 40 are from a section of a leaf bearing teleutospores. A long teleutosorus lay along the midrib and beneath this an internal sorus had developed. It was therefore an extreme case of heavy teleutospore production. The intercellular spaces are packed with mycelium and one or more haustoria are in almost every cell. Yet only in the thick-walled cells near the sori are haustoria with thickened walls found (FIG. 38). In the thin-walled inner parenchyma of the storage tissue around the midrib the numerous haustoria are all slender-stalked forms with no thickening (FIG. 40). Figure 40 is a good illustration of the typical nuclear condition of haustoria of the corn rust: the haustorium is multinucleate; the nuclei occur in conjugate form, agreeing with the expected condition for uredo-teleuto mycelium. Such median optical views as that of the haustorium in figure 39 show nuclei in the basal part as well as in the lobes.

In all these cases figured in plates 2 to 4, the thickening of the haustorial boundary, whether by a deposit of the host cell or not, seems to be a phenomenon correlated with the yellowing tissue and the much thickened host walls. The existence of such a correlation is confirmed by the comparison of haustoria from 'green island' tissue with haustoria from yellowed infection areas in a green leaf, the normal condition of advanced infection. Haustoria from the yellowed areas have been described, and are figured on plate 3. The difference between these sheathed forms and the haustoria in green tissue is strikingly shown in figures from a leaf strip which extended across a yellowed patch bearing two uredosori into green leaf tissue (see plate 5). In the green tissue no mycelium is found, and the plastids of the bundle sheaths show starch grains. In the yellowed tissue no starch shows, the mycelium is abundant, and there are haustoria in most of the cells. Figures 41 to 43 show cells from the edge of the yellowed tissue near the green. The cells are surrounded by abundant mycelium and are hypertrophied, but the haustoria are seldom sheathed. The remaining figures show cells from the yellowed tissue. The haustoria here are of the sheathed types already figured as typical of advanced infection. In figure 44 a so-called digestion vacuole shows clearly between the apparently dead, deeply stained haustorium and the dense accumulation of host cytoplasm around it. This is a thick-walled cell near a sorus. In figure 45 thickenings are shown on the stalk of a young haustorium in an epidermal cell. In figure 46 secondary thickenings are evident in a thick-walled cell of a bundle. The basal socket of the haustorium takes the same deep stain as the secondary cell thickenings, while the thickening which nearly covers the lobes is stained a paler purple. In figure 47 the cell walls are thickened at the places of penetration of two haustoria. In one case the wall thickening evidently kept pace for a time with the penetrating filament. The haustorium projects from a conical thickening which is distinctly laminated. The cells of this figure are beyond the sorus near a region of dead cells which lies between two seri. The cytoplasm in these dead cells is contracted around dense red-stained haustoria. Thus in this section one may trace a progression from slender-stalked haustoria in thin-walled cells near the green host tissue, to thickenings around haustoria and around intercellular hyphae in regions of thick-walled cells, and finally to dead haustoria in dead host cells. The dead area is limited in extent, lying between two infected areas.

Cells from the green-bordered sori are shown in figures 21 to 23, plate 2. Their haustoria agree in type with those on the same plate taken from leaves of less advanced infection. The intercellular spaces of this tissue are crowded with hyphae, and haustoria are numerous. They catch the eye even under low power, as they stain deep purple with the triple stain, while the host tissue and the intercellular hyphae, except for terminal cells, stain orange. Occasionally a terminal hyphal cell or a haustorium stains red. Occasionally a haustorium stains orange with a red nucleolus like the host nucleus. In figure 22 the upper haustorium is stained like the host nucleus, while the other two haustoria in the cell are deep purple. The striking thing about all the haustoria from these heavily infected green areas is the slender stalk. There is no trace of sheathing; yet, judging from the ripe sorus which lay near the epidermal cell of figure 23 and the abundant intercellular mycelium shown in figure 21, this tissue is in an advanced stage of infection. The uninfected cells beyond the green areas are poor in cell contents with faintly stained plastids. This agrees with the observation of Mains (1917) that the infected cells of a green spot draw upon the surrounding uninfected cells until, under the influence of the rust, the infected cells become parasitic upon the uninfected.

In addition to thickenings around haustoria and thickened walls of infected cells, I have found in corn leaves heavy, deeply stained walls in groups of cells near the limits of an infection area. In the leaf section described in connection with plate 5, these deeply stained cell groups stand out in the regions between the sori. In these same regions there are many dead cells with collapsed walls and plasmolyzed contents around dense, red-stained haustoria.

The appearance of thickened host cell walls in such cases is not easily explained, and, so far as I have found, has been noted only a few times in the literature. The staining tests which I have made do not determine definitely whether the deeply stained walls show secondary thickening or are gelatinized. The staining reactions are generally like those of thickened host walls.

These thickened spots suggest the condition which Magnus (1897) describes as caused by *Aecidium Magellanicum* in the barberry. The fungus causes a general stimulation of the tissues, resulting in witches broom formations, and also in a local toxic action upon the infected cortical cells of these shoots. The cells between which the hyphae run, and in which they form knotted haustoria, develop abnormally thick brown walls until the groups lie like islands in the midst of thin-walled tissue. Conversely, the mycelium seems to be injured by this contact. Frequently these thickened cells, together with the dead brown hyphae and the knotted haustoria (a pathologic group according to Magnus), are cut off by a ring of cork. Allen (1923) calls attention to increased thickness in host walls as a possible evidence of resistance by Kanred wheat to toxic secretions of rust. The thickenings which she describes, however, were between dead cells and normal ones and were least developed at the intercellular spaces, the usual place of entrance for haustoria. They appear to be much less pronounced than those I have found in corn. These deeply stained cell groups in the corn seem very different also from the swelling of the host cell walls which Allen (1923) describes as a secondary effect of *Puccinia graminis Tritici*, form 3, in resistant Mindum wheat. She states, 'These swollen walls take no stain (with the triple stain at least) and are transparent . . . such a wall must be almost lignified.' Dickson, Eckerson, and Link (1923) think that the factor which checks the penetration of corn and wheat seedlings by *Gibberella Saubinetii* is a maturation change in the cell membranes of the cells of the cotyledon sheath. At the outset, they state, these sheaths are composed of easily penetrable pectin. At maturity cellulose or even lignin and suberin predominate 'and these less easily hydrolyzable wall elements resist the invasion of the fungus.' Holbert and Koehler (1924) report thickened walls of pith and cortical cells of roots to be a distinctive character of certain strains of corn which are resistant to rootrot and smut.

The figures shown in plates 1 to 5 were selected with the purpose of comparing haustorial development under varying conditions of host tissues. I have called attention in several figures to instances of contacts between haustorium and host nucleus. A summary of conditions concerning contact as shown in these plates should, I think, give the typical habit for the corn rust, inasmuch as the figures were chosen by chance, so far as the matter of contact is concerned.

I find that the haustorium is very frequently in contact with the host nucleus. This does not seem to me to be due necessarily to specific action on the part of the host or the parasite. I find no evidence of an approach to the haustorium by the host nucleus. The nucleus is not generally found at the penetration spot of the young haustorium, as Allen (1926) finds it in infected cells of resistant wheat. It is in other positions or not in view in the figures of young haustoria (PLATE 1). Figure 12, plate 1, is an exception, in showing the nucleus near the young haustorium. The host nucleus is rarely found near the haustorial stalk or near the origin of the haustorial lobes. Figure 14, plate 2, and figure 26, plate 3, are the only examples of the nucleus in this position which I have noticed. The host nucleus certainly does not appear to seek out the growing point of the haustorium.

My figures show that the host nucleus is not infrequently more or less in contact with the lobes of the mature haustorium (FIG. 31, PLATE 3). It may more rarely be enwrapped by the haustorial lobes. In many cases the contact between the nucleus and a haustorial lobe is so close that the nucleus may be said to be amoeboid and to enwrap the haustorium, or the haustorial lobes may be said to be indenting the nucleus (FIG. 13, PLATE 1; FIG. 39, PLATE 4). Such situations as those shown in figure 22, plate 2, and figure 35, plate 4, where haustoria from different sides of the cell converge upon the host nucleus, suggest strongly that the position is due to more than chance, and suggest a positive tropism of the haustorium in relation to the nucleus.

These contacts seem as frequent in fresh green corn tissue as in the yellowed tissue. In the latter, however, there are more evidences in the nuclei of abnormality due to the contacts. In figure 13, plate 1, the host nucleus, although indented, is normal in size and contents. The nucleus of an uninfected cell from this section may be compared in figure 2, plate 1. These preparations are taken from material which had not yet produced spores. Even in material with erumpent sori the nuclei are, as a rule, only slightly hypertrophied. The strongly hypertrophied nuclei shown in figures 35 and 39, plate 4, are rare in corn. These were found in heavily rusted leaf-sheath material.

Of seventy-five sketches made from various tissues of corn, and at various histogenetic stages, thirty-three show the host nucleus in the vicinity of the haustorium. A count of nuclear contacts was made from the material sketched in plate 3; from twenty-seven microscopic fields, averaging twenty cells to a field, fifty-six haustoria were counted without the host nucleus in view, and sixty-three with the host nucleus showing. Of the latter, all but two showed contact between nucleus and haustorium. The low average of only four out of twenty cells to a field which show haustoria does not express the degree of infection for this material, as the many cells containing only cross sections of haustorial lobes were omitted. These cells were considered indeterminate with respect to the relative positions of the host nucleus and the haustorium.

Effects of rust on reserve carbohydrates

Attempts to determine food conditions in the leaf of the corn host require a recognition of certain anatomical and physiological characters of the corn. Stevens (1916) states the facts briefly and clearly:

> In Indian corn each of the veinlets is surrounded by a sheath of border parenchyma cells and these in turn by palisade cells radiating from them. . . . In corn, as indeed in many grasses, starch is not formed in the palisade cells at all but the parenchyma sheath on bright days is filled with it. . . . Of course the palisade cells manufacture soluble carbohydrate abundantly and the starch in the sheath cells doubtless represents a surplus that comes to the sheath faster than it can be conducted away.

This localization of the starch storage is proved by the iodine test. Corn leaves treated with iodine darken only along the bundle lines. Healthy leaves were used as a control for tests of rusted leaves. When infected leaves which showed a yellowed zone around the rust sori were treated with iodine, the darkened lines of the bundles were interrupted in these regions. Starch was evidently not present in the bundle sheaths in these yellowed zones. This agrees with the results reported by Mains for stages of rusting when the drain upon the host becomes so heavy as to prevent starch storage.

The sheath cells of the bundle in the corn leaf seem to be more crowded with plastids than the mesophyll cells, and their plastids seem less quickly subject to disorganization. Pale leaves striped with green along the bundles are a familiar phenomenon in a corn field. Apparently this may result from a variety of causes, but the chlorophyll seems regularly more persistent in the bundle sheaths. When normal leaf tissue is stained with the triple stain, the plastids in the bundle sheath cells stain deep red, while those of the mesophyll stain much paler. In rust-infected areas this tendency of the plastids of the sheath cells to stain deeply is lost. They stain the same pale red or yellow as do those in the surrounding mesophyll cells. The loss of chlorophyll, the external sign of infection, thus seems to correlate with lessened staining capacity in the plastids of infected areas. This reaction is not dependent upon the presence of haustoria in the sheath cells themselves. Even in advanced infections the sheath cells are seldom invaded. The mesophyll may be crowded with intercellular hyphae and with haustoria, but the fungus usually stops abruptly at the sheath circle. Figure 46, plate 5, shows an exceptional case of a haustorium in the parenchyma of a bundle. Mains (1917) states of the corn rust, 'The vascular bundles are apparently never invaded by the mycelium and the parenchyma sheaths which surround them only occasionally have haustoria in their cells.' Mains also notes the indirect effect of the rust upon the uninvaded sheath cells, 'Since the parenchyma sheaths serve as a storehouse for the assimilated material from the adjacent region, and since they are not invaded for some time, it would appear that this loss of starch is due, not to a withdrawal of starch from the parenchyma sheath by the fungus itself, but to the utilization by the fungus of the material formed in the neighboring region before it reaches the parenchyma sheaths.'

My best results in differentiating starch in the chloroplasts of the corn leaf were obtained with fixation in 50 per cent alcohol, followed by the triple stain. This was the preparation of the material used for the figures of plate 5. The mature rust sori of this material lay in a yellow area, but one end of the section extended into green tissue. It is in this end only that starch is shown in the bundle sheath cells. The starch grains are stained pale blue, and the plastids yellow. No starch is differentiated in the plastids of the mesophyll cells.

Haustoria of other rusts

I have studied for comparison, but in less detail, the haustoria of several other rusts. The forms illustrate the first three types given in Arnaud's classification of haustoria: the simple, the spiral, and the digitate. His fourth type, the coralloid haustorium, which is so abundant in the Asterineae, I have not yet found in the Uredineae.

Puccinia claytoniata Peck. Plants of *Claytonia virginiana* heavily rusted with *Puccinia claytoniata* were gathered in May, 1922. The rusted leaves are slightly thicker than the normal leaf. Spermogonia and aecidia were both erumpent. Some yellowed leaves were crowded with aecidia on both surfaces. Other leaves showed only spermogonia and were still green. Figures 48 and 49, plate 6, show cells from this younger, green material. The tissue shows a heavy infection, with spermogonia just breaking the epidermis. In their vicinity the hyphae make a felted mass. Throughout the leaf, hyphae crowd the intercellular spaces. Unlike the corn rust, they invade the intercellular spaces of the vascular bundles, and send haustoria into the wood parenchyma cells, and even into the vessels. The haustoria are elongated vesicles, bent or twisted, but for the most part unbranched. Only occasional encased forms in epidermal cells resemble the short, knob-like forms described by Fromme (1914) for the same rust. Figure 48 shows a haustorium overlying a lobed host nucleus and surrounded by cytoplasm and plastids. Lobing and hypertrophy of the host nucleus and contact between host nucleus and haustorium are more frequent in the infected *Claytonia* tissue than in the case of the corn rust. The cytoplasm of the host cells is regularly set with plastids close to the wall. Their position in figure 48 indicates invagination. The massing of cytoplasm around the haustorium seems evidence that cell activities center in the vicinity of the haustorium. In figure 49 a binucleate haustorium is enclosed in dense layers of cytoplasm. Cytoplasm frequently makes an irregular coating over the heavily encased knob-like haustoria of epidermal cells. These conditions agree with that described by Allen (1923) as a reaction of Mindum wheat to *Puccinia graminis Tritici* and support her suggestion that the haustorial sheath originates from host cytoplasm. All degrees of sheathing are found in the infected *Claytonia* tissue, and its occurrence is always coincident with some degree of thickening of the host cell walls. The mesophyll cell of *Claytonia* is normally thin-walled. In figure 48 the haustorium issues from a basal socket which seems continuous with the thickened wall of the host cell. Both are shown in black in the figure. In figure 49 the host cell wall is much thickened at the point where the haustorium entered. This may be a swelling due to parasitic action, but similarity in staining reactions indicates strongly the common origin of this host cell wall and the haustorial sheath.

Puccinia Violae DC. Figures 50 and 51, plate 6, are from leaves of *Viola cucullata* infected with the uredo stage of *Puccinia Violae.* Mycelium was abundant throughout the leaf tissue, but the sori were overrun with an infection of *Darluca filum* which had fruited abundantly and formed dense stromata at the base of the sori. I did not find haustoria of *Darluca.* The hyphae of *Darluca* are distinguished by their smaller nuclei, and they are closely appressed to hyphae of the rust. The haustoria of the rust may issue from a basal socket, or they may be completely encased in a thick wall (FIG. 50), or they may have merely a thickened tip (FIG. 51). Those with thickened tips appear similar to the ones described by Colley (1918) for *Cronartium ribicola.* Many of the violet cells are nearly filled with a yellow-staining homogeneous substance. Figure 50 shows this indented by the haustorium. The small host nucleus is shown in figure 51. This is typical both in its faint staining reaction and in the lack of differentiation of a nucleolus. It is not typical, however, in its nearness to the haustorium. The haustorium is only infrequently found in the vicinity of the host cell nucleus. The haustoria are usually binucleate. The two figured have triple nuclei. These are frequent enough in the material to indicate that the haustorium does not necessarily have the same number of nuclei as ordinary hyphal cells.

Aecidium punctatum Pers. In the fall of 1923 three plants of *Hepatica acutiloba* were transplanted from the vicinity of Pittsfield, Massachusetts, to Norton, where *Hepatica* does not occur. In the spring of 1924 one of the group developed rust upon its new leaves. This same plant developed rust in 1925, while the other two plants in the group remained uninfected. In 1926 the rust developed also on another of the three plants.

Accidium punctatum is very favorable material for the study of haustoria. In the infected area around a sorus, haustoria occur in almost every epidermal cell, as well as in the mesophyll cells. Figure 52, plate 6, shows a haustorium in a mesophyll cell. Although the leaf was completely dotted with spermogonia and was altered into a smooth erect form, it was fresh and green. The cell figured shows apparently healthy conditions of cytoplasm, plastids, and nucleus. The haustorium coils abruptly after entering the cell, and then extends a twisted lobe into the vicinity of the host nucleus. The base of the haustorium seems more thickly walled than the lobe. There is great uniformity in haustorial form and habit throughout the infected tissue.

Puccinia Asterum Kern. Figure 53 is from a section of a leaf of *Solidago* sp. infected with *Puccinia Asterum*. This is another case in which the mutualistic relation between host and rust is obvious. The only indication of any abnormality in the host cell is the presence of red-stained bodies which are possibly waste products. The cells of this leaf are fairly thick walled; yet there is no indication of any sheath around the haustorium. A well defined clear area appears around both the longitudinal and cross sections of the haustoria. Both of the lobes are in close contact with the host nucleus. The binucleate haustorium is of interest on this aecidium-bearing mycelium.

Uromyces appendiculatus Fries. Figure 54 shows a simple sac-shaped haustorium from an infected leaf of Kentucky Wonder

Bean. The slender, stalked vesicle, with its vacuolated cytoplasm and reticulated nucleus, is well differentiated. The host cytoplasm and plastids are massed in the vicinity of the haustorium. The plastids in the tissue below the sorus, the region of the cell figured, are contracted and are stained pale yellow. In the tissue on either side of the sorus the plastids stain bright red.

Uromyces houstoniatus Schweinitz. This species is apparently perennial in *Houstonia caerulea.* Infected plants are etiolated, and are noticeable in the field because of their pale yellow color and greater height. Stems, leaves, and buds showed erumpent spermogonia and aecidia. Material was fixed in Flemming's medium solution in May, 1923. The mycelium is abundant in the intercellular spaces of all these tissues, forming runners in the parenchyma and the bundle sheaths of stem tissue, and entwining the cells of growing points and leaves. The haustoria are long hypha-like diverticula, occasionally branched, always much curved and twisted so that it is difficult to get a complete view of one. They frequently enwrap the host cell nucleus. In epidermal cells near the spermogonia, and in bundle sheath cells, the haustoria are at times thick-walled, but in the majority of cases they show no thickenings. Figure 55 shows a cell from leaf tissue. This haustorium is unusual in having a branch. Its cytoplasm also shows an abrupt change from a deep blue stain up to the origin of the branch and a pale stain in the terminal half. What G. Smith (1900) called a digestion vacuole is well defined around the base of the haustorium. The tip of the haustorium evidently curves into another plane.

Uromyces Caladii Farlow. I have studied a plot of rust-infected *Arisaema* for three seasons at Norton. Spermogonia and aecidia develop each May upon the unfolding leaves and floral parts. As a rule even heavily rusted leaves and spathes develop rather normally. All parts of the *Arisaema* shoots are heavily infected with the rust, the intercellular spaces being stuffed with mycelium. Several corms of infected plants were fixed and sectioned but no trace of the mycelium of the fungus was found. More work is needed to determine whether this rust 'repeats' by means of an annual infection from spores in the soil, instead of living as a perennial mycelium. My negative findings at least suggest the possibility that this is another case like that found by Whetzel, Jackson and Mains (1924) for the rust on *Podophyllum.*

The infection appears, however, typically systemic. The haustoria show helix-like coils in close contact with the host nucleus. These conditions are shown in figure 56, a cell from the layer just below the columnar epidermis of the smooth tip of a spadix. In the section almost every cell of this layer showed one or more haustoria. The spongy tissue within was also heavily infected. The epidermal layer had few haustoria, although spermogonia dotted its surface. The rust grows with great luxuriance in the soft succulent tissue of *Arisaema*. In certain prepared sections of the stem where the host walls happened to stain very faintly, the pattern of the host cells appeared outlined by the fungus. The hyphae encircle every cell, and haustoria penetrate from each intercellular space. It is to be noted that the thin walls of the host tissue correlate with the general absence of thickened boundaries around the haustoria. Only in cells near spermogonia was an occasional instance found of a haustorium with thickened boundary.

Aecidium Sambuci Schweinitz. *Sambucus canadensis* was found in Norton in June, 1922, heavily infected with *Aecidium Sambuci*. The rust formed yellow galls on the young stems, the petioles, and the mid-ribs of leaflets. An intercellular mycelium is abundant in these galls. Slender, deeply stained hyphae encircle the hypertrophied cells (FIG. 58, PLATE 7). Almost every cell throughout the gall is penetrated by haustoria. The cells of the bundle sheath are frequently entered (FIG. 57). The haustoria are ribbon-like (FIG. 58), or arborescent (FIG. 57). More rarely the slender-stalked sac typical of the corn rust is found. There is an appearance of activity in the cells under the stimulus of the fungus. Hyperplasia is common in the host cells. Figure 58 is an example, showing a haustorium in contact with a host nucleus in prophase.

Chrysomyxa Pyrolae Rostr. *Chrysomyxa Pyrolae* occurs in Norton, Massachusetts, in the spring on the overwintered leaves of *Pyrola americana*. The orange uredosori appear in early May, covering the under surface of the leaves. About two weeks later the paler yellow teleutosori appear in scattered groups among the uredosori. The habit of this rust makes an interesting contrast to *Aecidium punctatum*, which I have described above. *Chrysomyxa Pyrolae* apparently overwinters in the rootstock and terminal bud of the host; the uredo and teleutospores appear on the leaves, usually, only in their second year. *Aecidium punctatum* seems, from its recurrence on the *Hepatica* plant studied, to be also a perennial rust, but its spermogonia and aecidia develop on the spring leaves as they unfold.

Pyrola leaves bearing uredosori only are well supplied with starch. The large storage grains are massed in the mesophyll cells. They are enclosed in the cytoplasm and are often crowded to the wall by a dense homogeneous substance which fills the vacuole. This seemingly mucilaginous substance occurs throughout the mesophyll. It is of similar appearance to the vacuolar content already noted in the cells of *Viola cucullata*. It stains greenish yellow with the triple stain and with the Gram-Weigert stain. Figure 60 shows the starch grains lying upon the periphery of the dense yellow substance in the primordial utricle. A haustorium has pushed into the central mass. From this preparation it would appear that the haustorium has pierced the plasma membrane and lies in the mucilage vacuole. In figure 59, however, where a section of a haustorium is shown lying between two masses of mucilage, the haustorium is completely surrounded by a clear area within the host cytoplasm. Moreover the cytoplasm with embedded starch grains can be traced completely around the masses of mucilage. The mucilage vacuoles are here unbroken, and the haustorium lies apparently in a space due to invagination. Invagination is more clearly shown in the case of mere indentation of a mucilage vacuole by a haustorium. Such cases are common in the sections. Figure 64 gives especially clear evidence for invagination. The section was stained with the Gram-Weigert stain. Both host walls and the heavy haustorial sheath are pink. All protoplasm is deep blue and the mucilage is yellow. A continuous film of the blue-stained host cytoplasm can be traced around the pink-walled haustorium, showing clearly between this and the yellow mucilage.

In the sections of leaves bearing teleutosori, storage starch is not in evidence. This disappearance is probably due both to the fungus and to the growth of the young host leaves. Freehand sections of unrusted winter leaves, gathered when the young leaves of the plant were half grown, showed abundance of storage starch by the iodine test. This would indicate that the fungus is largely responsible for the disappearance of the starch in the infected leaves.

The haustorium is usually an unbranched inflated sac, but the tip is often recurved. A slender stalk shows in occasional sections (FIG. 60). The haustorium is typically binucleate (FIGS. 61, 62), corresponding to the binucleate condition of the mycelium. The nuclei lie in a granular cytoplasm which usually encloses a large vacuole at the tip of the haustorium (FIG. 62). Contacts between host nucleus and haustorium are rare. Haustorial sheaths are also less frequent than in the case of either *Puccinia Sorghi* or *Puccinia claytoniata*. The thickening shown around the base of the haustorium in figure 62 is stained blue with the Gram-Weigert stain, and so indicates layers of host cell cytoplasm rather than extensions of the host cell wall. Not infrequently instances are found of apparently dead haustoria with dense blue-stained cores encased in heavy pink-stained walls (FIGS. 63, 64). Figures 61 and 64 show cells just within the lower epidermis, and show the wide intercellular space between this layer and the epidermis, caused by the network of hyphae from which the sori arise.

GENERAL DISCUSSION

It becomes apparent through examination of rust-infected tissues that, important as the haustorium undoubtedly is for the life of the fungus, the fungus is not entirely dependent upon this organ for its nutrition. The early infection stages of the corn rust show an abundance of intercellular mycelium and well developed runners with dense contents. This would indicate that during the early stages, before the development of haustoria, the fungus is able to draw some nourishment from the host directly through the host cell walls. Certainly the vigorous intercellular growth shown in plate 1 does not depend upon haustorial activity.

I have observed the same condition in *Chrysomyxa Pyrolae* upon *Pyrola americana*. The mycelium apparently overwinters in buds or rootstocks. Leaf material examined in April shortly before the formation of the uredosori shows an abundant mycelium in the mesophyll but few haustoria. After the sori have become erumpent, haustoria are much more numerous. W. Magnus (1900) reports for *Puccinia leucospermum* on *Anemone nemorosa* that the haustoria are relatively late in appearing, and he thinks the chief nutrition of the fungus during the formation of the spermogonial and aecidial anlagen must have been by way of the intercellular hyphae.

The rusts in such stages suggest in their host relations the thread blight of tea and *Acanthostigma parasitica*, which are described by Butler (1918). The thread blight of tea, a possible *Rhizoctonia*, abundant in India, spreads web-like films of sterile hyphae fan-wise on the under surfaces of the leaves. It causes a browning of the leaves, although the host cells are unbroken and the glistening strands of mycelium can be readily peeled off. *Acanthostigma parasitica* upon the pine has rudimentary haustoria. They are tiny outgrowths of the basal layer of the cushion-like masses of mycelium on the surface of pine needles and pierce merely the cuticle of the host cells. In both cases, Butler points out, the food passes through unbroken walls. The efficiency of such absorption methods is more comprehensible under Hansteen-Cranner's theory of the composition of the cell wall (1922). If the cellulose wall contains a network of the same proteins as the plasma membrane, then the two protoplasms will be in contact even by the mere external apposition of fungus and host cell walls.

Such data as the above do not minimize the importance of haustoria. They do, however, shift the emphasis in interpreting function. The mature haustorium effects a great increase of surface for absorption. Moreover, for the unencased haustorium at least, the absorption would be through fewer layers than in the case of the intercellular hyphae, since the haustorium penetrates the cell wall.

I have not observed in the corn rust any mucilaginous secretion under the appressorium, such as is reported by Brown (1915), Dey (1919), Boyle (1921), and Waterhouse (1921) as present under the tips of the penetrating hyphae of *Botrytis cinerea*, *Colletotrichum Lindemuthianum*, *Sclerotinia Libertiana*, and the germ tubes of the sporidia of *Puccinia graminis*. Although the resistance to displacement gained by such an attachment might possibly assist the act of penetration, Blackman considers it unnecessary. He has (1924) suggested that the essential preliminary to penetration is merely close adhesion of the tip of the hypha to the surface to be penetrated. He also holds that the adhering surface is so large, in comparison with a cross section of the peg-like penetrating projection, that but little pressure is needed to resist the back pressure resulting from the outgrowth of the infection tube and to push the projection through the wall.

Penetration by means of a slender filament, which is so characteristic of the haustoria of *Puccinia Sorghi* and other rusts, is, in its lack of digestive action, different from the process of penetration in the case of the facultative parasites. In the latter, according to Brown (1915) and Blackman and Welsford (1916), working with *Botrytis cinerea*, Dey (1919), working with *Colletotrichum Lindemuthianum*, and Boyle (1921), working with *Sclerotinia Libertiana*, although the cuticle is penetrated by pressure alone, enzymic secretions of the hyphae soften the cell tissues. *Rhizopus nigricans* has been shown by Stevens and Hawkins (1917) to secrete an enzyme which disintegrates cellular tissue by digestion of the middle lamella, and a toxin which, by killing the plasma membrane, allows leakage of the cell contents. These examples indicate a specialization of offensive metabolism by the parasite, rather than an evolution toward adaptation to the living host.

Lutman (1910) traces the origin of the haustorium in *Entyloma Nymphaeae* through two stages. First, he says, a hypha is pushed out against a cell wall, and there branches into a closely appressed appressorium. Under this the host cell wall becomes dissolved and a hypha is pushed down from the appressorium into the cell. The pentration hypha is much constricted, but soon swells into normal diameter and branches profusely into a tangled knot. Lutman supposes that perhaps originally appressoria alone were produced, and that the penetrating hypha is a further development.

An evolution of penetration is suggested by Allen (1926) for the Uredineae. In her study of rust on the resistant Khapli emmer she detects a toxic effect of the appresoria upon the guard cells of the stomata. Inasmuch as such a secretion would not assist the fungus through the stoma, she suggests that 'the appresorial secretion is a survival from an earlier period in the evolution of the fungus when it did secrete enough to dissolve its way into the host.' She found no such secretion in connection with the haustorial penetrations. In her description of penetration into a susceptible host (1923) she mentions a red-stained spot on the host cell wall, which she believes indicates an alteration in wall composition due to enzymes secreted by the fungus. This is at the spot where the filament develops. Since the rest of the wall under the appressorium is unchanged, she thinks the appressorium less an organ of attachment than a storage reservoir, from which the cell contents can be transferred with the greatest economy to the nearest point of entrance into the host cell. I have not found evidence in the corn rust of any alteration in the host cell wall at the point of entrance. The corn rust illustrates the statement of Bolley (1906): '[They] are such perfect parasites that the hyphae pass directly through living cell walls of the host and make practically perfect fusions with the cell-walls.'

That in young stages a hyaline zone intervenes between the haustorium boundary and the plasma membrane of the host cell is shown in my figures of plate 1. Apparently this later becomes the digestion cavity. That the haustorium invaginates rather than penetrates the cytoplasm seems clear from figures 29, 38, and 64. There seems to be general agreement on this point in the literature. However, we need clearer evidence as to whether each branch of a digitate haustorium has a special sheath of host cytoplasm, or whether the whole complex lies in a single rounded indentation of the host cytoplasm. This latter seems to be the case, for the branched haustoria of *Erysiphe graminis* (see fig. 19 by G. Smith, 1900). Leitgeb (1881) gives a graphic description of the cytoplasm of the fern prothallial cell streaming around the haustorium-like processes of *Completoria complens* and carrying the plastids in its stream. Such streaming is supposed to leave the plasma membrane immobile. By the establishment of haustorial lobes within folds of an invaginated plasma membrane, a condition for effective absorption is attained. The failure to rupture the primordial utricle is, I believe, the mark of an adapted parasite, an evidence of an approach to mutualism in the haustorial parasite, with its immediately destructive action reduced to a minimum.

Elaboration of form in the haustorium is another evidence of a high degree of adaptation by the haustorial parasite in securing maximum contact relations with the host protoplasm. The varied forms reported from the literature and from my own investigations, which I have grouped under Arnaud's four types, are merely elaborations of the oblong sac. The delicacy of the adjustment in this matter is particularly striking in the case of variation of form within one host. The characteristic haustorium of the corn rust in parenchyma cells is the two- to several-lobed, digitate form which I have so often figured. In the epidermal cells, on the other hand, one finds more often simple sacs or reduced button-like forms. The many variations in form described in the literature indicate that haustorial form is a physiological as well as a morphological reaction.

The multinucleate condition so frequent in haustoria is another evidence of plasticity in the organ. Although my tabulation from the literature shows that in general haustoria have a single nucleus or paired nuclei, according as they arise from a gametophytic or sporophytic mycelium, the number is larger in the lobed forms.

Data upon the space relations of the haustorium and the host protoplast most frequently deal with the contact between the haustorium and the host nucleus. This emphasis upon the nucleus may be due in part to the fact that it is generally regarded as a center for the metabolic activities of the cell. There are interesting statements in the literature as to the persistence of the nucleus in infected cells. Magnus (1900) reports that in infected tissue the host cell nucleus often long outlives the rest of the protoplasm. Osner (1910) reports that in the sori of Timothy smut the host cell nucleus is the last thing to disappear before spore formation. Arzberger (1910) writes of the mycorrhiza in *Eleagnus argentea*, 'Thus there is a long continued struggle between the host and the fungus resulting finally in the destruction of the cell, the nucleus being its most resistant part.'

The evidence in the literature appears to favor the view that there is an attraction between host nucleus and haustorium. I have listed twenty-three cases of habitual contact, against nine cases of occasional contacts, and three negative cases. In view of the numerous positive findings, these negative cases are perhaps to be regarded as due to special and exceptional conditions.

The interest in these data as to contact relations between haustorium and host nucleus centers in the bearing they have on problems of the physiological relations within the cell. Statements as to the initiation of the contacts fall under two heads: first, contacts due to host-nuclear control; second, contacts due to reaction by the haustorium. The assumed action of the host nucleus it is thought may be protective. Guttenberg (1905) in the case of *Ustilago Maydis*, interprets the contact of host nucleus and haustorium as a means of initiating the building of a cellulose sheath around the haustorium by the host cell. Colley (1918) also believes that the cellulose sheath which he finds around the haustoria of *Cronartium ribicola* is a means of defense by the host cell, but he finds little evidence that the nucleus is in any way concerned.

The action of the host nucleus may be offensive. Magnus (1900) ascribes to the influence of the host nucleus the reduction of the haustoria of *Puccinia Xanthii* to formless masses. It is the explanation given by Němec (1911) for the relations of host nucleus and haustorium in *Uromyces Betae* on the beet. Němec thinks that the haustorium is drawn into contact by the host nucleus and that, through this contact, degeneration and death of the haustorium ensue. Němec calls this nuclear action a temporary phagocytic activity of the host. At other times he finds the nucleus ineffective in its offense when a new branch may be put out by the haustorium below the degenerate tip. One of the phenomena which Allen (1926) describes in the relations of *Puccinia graminis Tritici* and the resistant host, Khapli emmer, is a host-nuclear offensive, initiated, she thinks, as a chemotactic response to substances diffused out into the host cell by the haustorium. The effect on the fungus she ascribes to secretion from the host.

The second explanation of contacts, as due to reaction by the haustorium, assumes usually a positive tropism on the part of the haustorium, to further absorption. Thus Sappin-Trouffy (1896) regards the contact of haustorium and host nucleus as a means by which the parasite draws to itself the products of the host cell metabolism. Guttenberg (1905) states that the haustoria of *Puccinia Adoxae* grow toward the host nucleus in order to absorb nuclear substances. He finds a similar tendency in the case of the haustoria of *Uromyces Alchemillae* in leaf tissue, but finds no contacts in the cells of petioles. Such an exception makes it appear that we are still far from any complete explanation of the relation of haustorium and host nucleus.

The growth of the haustorium toward the nucleus is rarely interpreted as an attack. Zach (1910), however, so describes infection by *Puccinia graminis*. He shows elaborate figures of a branched haustorium making a tangled network within the host cell nucleus. Both invader and nucleus, he states, are finally killed, and the infected hyphal-filled nucleus becomes a homogeneous, amorphous excretion body, with degenerate hyphae projecting from its surface as papillae. The figures suggest an intracellular hyphal fungus rather than haustoria.

These same problems of the relations between host cell nucleus and parasite are presented by the intracellular mycorrhizas. A comparison is the more interesting because, according to reports, one finds in the mycorrhizal complex a change in relations during the life cycle of the fungus. This is shown by the work of Groom (1895) upon *Thismia Aseröe*, Magnus (1900) upon *Neottia Nidus-avis*, Arzberger (1910) upon *Ceanothus americanus*, *Eleagnus argentea*, and *Myrica cerifera*. In all these cases the authors report that the fungus in the early stage grows at the expense of the host but with a controlled mutualism. In all but *Neottia Nidus-avis* the hyphae grow directly toward the nucleus. As the masses of intracellular hyphae increase, the balanced condition ceases. In *Thismia Aseröe* and *Neottia Nidus-avis* the host cell nucleus gains control and the fungus degenerates into tangled masses of hyphae, the sporangioles, from which the host cell is believed to draw some nourishment. In the forms studied by Arzberger the host cell never gains this complete control, although the hypertrophy of its nucleus is taken to indicate activity. In all three forms the parasite draws increasingly upon the host until both cytoplasm and nucleus of the host cell are killed and more or less absorbed. After this outcome, the fungus also dies, probably, Arzberger says, of starvation.

In my investigations upon various rusts I have shown that haustorium and host cell nucleus are frequently in contact. The appearance of the nucleus, however, even when enwrapped by the haustorial lobes, does not suggest offensive action on either side. According to Arzberger (1910) for mycorrhiza, and according to Zender (1924) for the haustorial cell which pushes out from the absorption process of *Cuscuta*, hypertrophy and lobing of the nucleus indicate phagocytic activity. There seems little indication of this in the case of rust-infected cells. I have noted that the nuclei are occasionally hypertrophied, but this hypertrophy I should interpret, as Allen (1923) does in the wheat, as a stimulation effect found in a susceptible host. The haustoria in these cases of contacts seem generally in active condition, as indicated by the density of their protoplasm. If there is special significance in the haustorium-nucleus contact, it seems to me more likely to be one involving absorption processes by the haustorium. We need clearer evidence as to the functions of the nucleus as a center of metabolic activities.

The peculiar, conspicuous, and highly stainable thickenings of, or sheaths about, the haustorial walls provide perhaps the most direct and at the same time the least understood evidence of the nutritive relations between the rusts and their hosts. That these structures are sheaths deposited by the host cell is perhaps the most generally accepted view, and in the case of the mildews it is clear that the sheath of the stalk is continuous with the cellulose wall of the host cell. In the case of the haustoria of corn rust, however, in many cases the ring and cup-shaped structure seem to be indistinguishable from a thickening of the wall of the haustorium. Such sheaths or thickenings, according to reports which I have listed from the literature, are certainly of wide spread occurrence. In these reports they are generally held to be an evidence of resistance by the host to the parasitic attack.

There is a marked difference in the time of their origin. In *Erysiphe communis*, as described by G. Smith (1900), their origin is very early. At first a thickening of the host cell wall keeps pace with the penetrating haustorium. Enzymic action by the growing haustorium gradually dissolves this, leaving the mature haustorium surrounded by a turgid digestion sac, and sheathed at the base by undissolved host cellulose. Colley (1918) reports a later origin for the sheath in *Cronartium ribicola*. He states that the sheath has not been found in connection with young haustoria in any case, but that proper staining shows around the mature haustorium a sheath, which is thick at its base and tip, and very thin in the middle region. Colley explains this peculiarity of structure as the result of response by the host at the two chief points of irritation, 'the point in the cell wall through which the haustorium entered, and the point of contact of the advancing haustorial tip with the host cytoplasm.' I think the objection may be raised here that any response to the irritation at the spot of penetration of the haustorial neck would naturally come early, when the projection filament is first piercing the host cell wall. Colley also suggests that the sheathing cup and cap are precipitation products laid down as the result of irritation in the narrow space between the haustorium and the membrane of the host cytoplasm. Allen (1923) describes a sheath for *Puccinia graminis Tritici* only in the case of extreme incompatibility between *Puccinia graminis Tritici*, form 3, on Mindum wheat. She interprets it as a cause of death to the haustorium. She notes the frequent massing of host cytoplasm around dying haustoria, and thinks this may have some relation to sheath formation. The sheath, she states, quickly loses its power to stain.

Many workers upon rusts do not report a sheath. Ward (1902b) does not describe one for *Uredo dispersa*, nor Evans (1907) for *Puccinia Sorghi*. If the sheath is a result of resistance offered by the host, its absence in certain rust species may be explained as indicative of well established mutualism in the host-fungus complex. Interpretations as to the significance of the sheath should be made only after a comparison of haustoria through the full life cycle of the rust and under varying host conditions. In my investigations upon various rusts, although I have observed some degree of sheathing in the majority of cases, I have obtained data for comparison only in the case of the corn rust. It seems to me that we have in the degree of development of the sheath or thickening around the corn rust haustorium an index of the degree of mutualism effected at the moment by the fungus and its host. In the early stages of the rust growth, including the penetration and development of the lobed haustoria, the absorption by the fungus is so adjusted that little reaction is set up by the host, and a sheath is rarely formed. In later stages the drain upon the host, evidenced externally by the yellowness of the infected areas, may stimulate the host to deposits of cellulose. Capacity for sheath formation would thus become a factor in the expression of immunity. It will be of importance to test this theory by testing the relative immunity of a large number of races of corn and at the same time the relative development of haustorial sheaths in the various combinations.

The effectiveness of a host cellulose deposit as a means of preventing absorption by the haustorium is so far untested. If cellulose walls allow the passage of food through them into intercellular hyphae, then cellulose sheaths can at best merely lessen the amount absorbed. A further point for study is the chemical nature of the so-called sheath. Chitin has been reported as occurring in the walls of many fungi. Wisselingh (1898) reports its occurrence in the Erysipheae (reported by G. Smith, 1900). Smith confirms Wisselingh's negative test with Congo-red as evidence for the occurrence of chitin in the Erysipheae, and adds:

> The walls of the haustoria do not show any reactions to stains that would indicate that they contain any different material from the remainder of the fungus.

So far as I find, the haustorial thickenings of the Uredineae have never been tested for chitin.

An indication of the effectiveness of the sheath in checking absorption may be gained from the condition of the enclosed haustorium. Colley traces in the haustorium a vacuolization of the cytoplasm, and a shrinking of the nucleus coincident with the sheath development. He states that this lessens the efficiency of the haustorium as an absorbing organ, but he does not say what he thinks is the direct cause of the degeneration. Allen, as mentioned above, connects the sheath with the death of the haustorium. The development of the sheath does not seem to bring degeneration to the haustorium of the corn rust. It is true the haustoria of the corn rust are seldom completely encysted, but when they are, a median optical section usually shows the nuclei of the haustorium still present (FIG. 39, PLATE 4). Occasionally the contents of the haustorium are reduced to a narrow strand (FIG. 38). The continued vitality of the enclosed haustorium is apparent in the many cases where non-sheathed lobes project from a heavily sheathed base (FIG. 39).

My study of many stages of rust-infected corn tissue, and of material from various other rusted plants, makes apparent the prevailingly normal condition of the plastids in infected cells. In their position and size there is little difference between the plastids of infected and uninfected cells. The lessened staining capacity observed in plastids of infected cells is not necessarily due to a toxic effect. Mains (1917) has suggested that the feeding fungus checks normal storage. Possibly this lessened staining capacity of the plastid is due to the same cause as that which Meyer (1918) demonstrates for the normal aging leaf, a drawing upon protein of the plastid for respiration, under shortage of carbohydrates.

I find reported eight cases of disorganization in the plastids of rusted tissue. Such cases as the coffee rust and asparagus rust seem to be the result of toxic action on the part of the rust, though they require further study.

The 'green island' phenomenon of infected tissue is strongly correlated with specialization in the parasite. As the literature shows, thirteen of the nineteen examples of chlorophyll persistent in infected tissue longer than in surrounding non-infected tissue are due to rusts. One of the other six is due to a haustorial fungus, *Uncinula Aceris*. The basic fact here is, of course, the prolongation of the life of the entire cell, and not merely the persistence of the green color. The stimulation of infected cells to a longer and possibly more active life than the adjoining cells is one of the least understood phenomena of parasitism. As a physiological effect it is perhaps to be classed as a less specialized case of those mycetogenous deformations and new formations which DeBary (1887) holds are 'in direct causal relations with the feeding of the fungus.' The difference between these 'green islands' and the gall formation is from this standpoint merely one of degree.

In the instances of 'green islands' which I have listed from the literature there is little discussion of their cause or of the relation of the phenomenon to resistance and susceptibility. The reference from Eriksson and Henning (1896) is merely to two colored figures which show the green spots vaguely. They are not discussed in the text, which is concerned with the relation of teleuto- to uredospores in the aging leaves figured. The series of colored figures of rusted oat leaves, however, does show clearly the contrast between the shift from pale green borders to yellow borders around sori on green leaves, and green borders around sori on the old, reddened leaf. The reference from Carleton (1899) is also to a colored figure. It shows very clearly the green-bordered sori on a red, basal, rye leaf, but Carleton's description of the figure notes merely that 'the chlorophyll remains about rust spots during changes of the coloring matter.' Mains (1917), the first one in my list to give any detailed consideration to the persistent green spots, interprets them as evidence that the infected cells levy upon the uninfected cells surrounding them. 'It would thus appear that the rust thus destroys the symbiotic balance between the cells of the host and causes some of them to have parasitic relations with the rest.' This interpretation does not touch the cause of the phenomenon, but Mains in his description of infection experiments with *Puccinia Sorghi* notes that the green spots appear 'when limited areas of the leaf are infected.' He calls attention to them in the cases of abortive infection on corn plants which were subjected after inoculation to unfavorable degrees of temperature or moisture, or to air lacking carbon-dioxide.

I think the fact should be more strongly emphasized that the 'green island' is most strikingly developed when causes other than the fungous infection have started deterioration in the surrounding tissue. Consideration of the subnormal condition of the adjacent host tissues should, it seems to me, be the starting point for any discussion of the physiological problems involved in the 'green island' phenomena. In the normal course of the infection of a vigorous host, any microscopic evidence of a symbiotic adjustment between host and parasite is often obscured by the heavy drain from the host by the parasite, but when other agencies tend to inhibit host development, the delicate adjustment between parasite and host becomes especially evident, and one may find the fungus effecting a preservative action upon the infected area. The water-soaked corn leaf which I described is an illustration. In this case the death of the surrounding tissue was not due to the infection.

In several of the cases listed from the literature the inhibiting factor upon the host may be inferred from the descriptions. Upon this basis they may be re-arranged as follows:

Factors inhibiting spreading infection in host tissue

1. Lack of water			
(a) Due to aging of the leaves			
	Eriksson and Henning,	*Puccinia coronata,*	*Avena*
	Carleton,	*Uromyces rubigo-vera secalis*	Rye seedling
	Thomas,	*Septoria Apii*	Celery
(b) Due to injury			
	Galloway,	*Coleosporium Pini*	*Pinus*
(c) Due to reduction in water supply			
	Mains,	*Puccinia Sorghi*	Corn
2. Lack of carbon-dioxide			
	Mains,	*Puccinia Sorghi*	Corn
3. High temperature			
	Mains,	*Puccinia Sorghi*	Corn
4. Reduction of light			
	Long,	*Puccinia graminis*	Wheat
	Long,	*Puccinia coronata*	Wheat

5. Hypersensitiveness

Stakman,	*Puccinia graminis Secalis*	Rye
Fromme and Wingard,	*Uromyces appendiculatus*	Bean
Allen,	*Puccinia graminis Tritici*	Khapli emmer

Allen does not note the 'green island' occurrence in a susceptible host, but she notes its frequent occurrence in the two less resistant forms of Khapli emmer. She notes it under inhibiting conditions of host growth, when 'the infected leaf dies prematurely.' She also interprets the 'green island' as a sign of balanced achievement in a resistant host, describing an actual change in the plastids as the result of the presence of the fungus. She states that the plastids, after shrinking and so causing the initial pale fleck which indicates lack of adjustment between resistant host and toxic pathogene, regain their normal size in the central cells of the infected spot, and cause a persistent green spot in the midst of impoverished or collapsed cells. Allen sees in the whole reaction less a question of food supply than of secretions, which finally stimulate instead of poison.

This recovered condition of the infected cells corresponds apparently to the balanced condition between rust and host cells in a susceptible host. Reduced virulence during what may be compared to the incubation period in the case of certain bacterial parasites is known among both smuts and rusts. Thus a smut, until the time of sporulation, is quite innocuous to its green host. Among the rusts such lessened virulence is even more striking in certain species which have a perennial mycelium. Such a condition is described by Hartig (1882) for *Melampsora Geoppertiana* upon the cowberry. During its first year the mycelium spreads through the cortex without any stimulation effects. Only in the second year are the long quill-like hypertrophies formed, upon which teleutospores develop. Kursanov (1917) cites the prolonged dormant period of *Melampsora Pyrolae* as a case of reduced virulence. He thinks it overwinters in the terminal bud, but it does not make itself evident in the leaves developed from this bud until the second spring. I have made observations upon this rust, which recurs annually in a plot of *Pyrola americana* at Norton, Massachusetts. Both in the fall and in the spring before the rust's appearance in the leaves, I have found a healthy, although scanty, intercellular mycelium in bud scales and rootstock.

That there is actually a mutualistic relation between rust parasite and host is of course hardly conceivable. However, the relations between the cells of host and parasite, as I have observed them in various rusts, are indicative of reduced or entire absence of toxic action on the part of the parasite. Its cells relate themselves to those of the host as do its own heterotrophic and storage tissues. Even wheat rust, perhaps the most destructive parasite which we have, is highly specialized in its reduced toxic effect on the host. Allen (1923) writes of a seven-day infection in susceptible Baart wheat, 'Here, as in the younger material the host cell gives every evidence of functioning normally or even with somewhat heightened activity, and host and parasite seem fully congenial.' There are cases of hyperparasitism among the rusts. Stevens and Hall (1910) lay the slight economic importance of *Puccinia Sorghi* to the fact that it does not usually develop early in the season. My cytological studies point to reduced toxicity and controlled feeding as added reasons for the lesser injury done by this parasite. I think there are indications of some such control in the case of the other rusts studied. *Claytonia* plants infected with *Puccinia claytoniata*, and violet plants with *Puccinia Violae*, blossom abundantly, notwithstanding rust-spotted leaves. *Houstonia* infected with *Uromyces houstoniatum* becomes so etiolated that the yellow, slender plants are easily detected in the field, but the plants are not killed; they blossom and fruit even with rusted calyx. *Aecidium punctatum* causes sterility in *Hepatica acutiloba*, but the rusted leaves, although metamorphosed, are green and vigorous. In the plot of *Arisaema* infected with *Uromyces Caladii*, which has been under my observation for four years, even when spermogonia and aecidia are abundantly developed, the leaves are not discolored; in September ripe fruit and a few persistent leaves show that the plants carry out their full cycle. The climax of hyperparasitism among the rusts is found in *Chrysomyxa Pyrolae.* Whereas *Puccinia graminis* infects the young wheat plant and, in coming to maturity, impoverishes the maturing host, *Chrysomyxa Pyrolae* appears on the leaves of *Pyrola* at the end of their career in the spring. In the plot of infected *Pyrola americana* which I have observed for four successive years, the layer of uredosori and teleutosori so thickly covers the under surfaces of the leaves that their brilliant orange is striking in the undergrowth of the grove. The entire lower epidermis is torn away by the erumpent sori, but the leaves show little discoloration. The excessive sporulation of the fungus does not prevent the new leaves of the host from developing normally and making a healthy plot of large shining leaves each year. I have also found fruited stalks in the fall. Kursanov (1917) considers that either the *Pyrola* leaf, or the mycelium, or both, must mature in some way before the conditions necessary for the fruiting of the rust are attained. He considers that the extraordinary length of this maturation process is a distinctive characteristic of this rust.

The cases which I have cited indicate that these rusts are all so hyperspecialized, even among the specialized rusts, that they do little damage to the host except at the time of spore production. For the Uredineae in general, I think that an elaborate development of the haustorium has furthered the lack of disturbance in the regions of special metabolism of the host-parasite complex.

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Literature cited

Adams, J. F. 1919. Sexual fusions and development of the sexual organs in the Peridermiums. Pennsylvania Agr. Exp. Sta. Bull. 160: 31–71. *f. 1–8 + pl. 1–5.*

————. 1920. *Darluca* on *Peridermium Peckii.* Mycologia **12:** 309–314. *pl. 21.*

Allen, R. F. 1923a. A cytological study of infection of Baart and Kanred wheats by *Puccinia graminis Tritici.* Jour. Agr. Res. **23:** 131–151. *pl. 1–6.*

————. 1923b. Cytological studies of infection of Baart, Kanred, and Mindum wheat by *Puccinia graminis Tritici* forms III and XIX. Jour. Agr. Res. **26:** 571–604. *pl. 1–7.*

————. 1926. Cytological studies of forms IX, XXI, XXVII of *Puccinia graminis Tritici* on Khapli emmer. Jour. Agr. Res. **32:** 701–725. *pl. 1–9.*

Anderson, A. P. 1897. Comparative anatomy of normal and diseased organs of *Abies balsamea* affected with *Aecidium elatinum.* Bot. Gaz. **24:** 309–344. *pl. 14, 15.*

Arnaud, G. 1910. Contributions à l'étude des fumagines. I. Sur un champignon parasite des Chênes. Ann. École Nation. Agr. Montpellier II. **9:** 278–288. *pl. 4.*

———. 1918. Les Astérinées. Ann. École Nation. Agr. Montpellier **16:** 1–288. *f. 1–22 + pl. 1–53 + maps 1–3.*

Arthur, J. C. 1903. Problems in the study of plant rusts. Bull. Torrey Club **30:** 1–18.

Arthur, J. C., & Johnston, J. R. 1917. Uredinales of Cuba. Mem. Torrey Club **17:** 97–175. *illust.*

Arzberger, E. G. 1910. Fungous root tubercles of *Ceanothus americanus*, *Eleagnus argentea*, and *Myrica cerifera*. Missouri Bot. Gard. Ann. Rep. **21:** 60–102. *pl. 6–14.*

Bachmann, F. M. 1913. The migration of *Bacillus amylovorus* in the host tissues. Phytopathology **3:** 3–13. *f. 1, 2 + pl. 23.*

Bagnis, C. 1875. Osservazioni sulla vita e morfologia di alcuni Funghi Uredinei. Atti Accad. Lincei II. **2:** 445–454. *pl. 1, 2.*

Bail, O. 1911. Das Problem der bakteriellen Infektion. Folia Serologica **7:** 1–3.

Bailey, C. H., & Gurjar, A. M. 1920. Respiration of cereal plants and grains. V. Note on the respiration of wheat plants affected with stem rust. Jour. Biol. Chem. **44:** 17–18.

Barclay, A. 1886. *Aecidium Urticae*, Schum., var. *himalyense*. Sci. Mem. Med. Officers Indian Army Part 2: 29–38. *pl. 2, 4, 5.*

Bary, A. de. 1853. Untersuchungen über die Brandpilze und die durch sie verursachten Krankheiten der Pflanzen. 1–144. *pl. 1–8.* Berlin: Müller.

———. 1863. Recherches sur le développement de quelques champignons parasites. Ann. Sci. Nat. Bot. IV. **20:** 5–148. *pl. 1–13.*

———. 1867. Ueber den Krebs und die Hexenbesen der Weistanne (*Abies pectinata* DC.). Bot. Zeit. **25:** 257–264.

———. 1884. Vergleichende Morphologie und Biologie der Pilze, Mycetozoen und Bacterien. 1–558. *f. 1–198.* Leipzig: Engelmann.

———. 1887. Comparative morphology and biology of the Fungi, Mycetozoa and Bacteria. Transl. by Garnsey & Balfour. 1–525. *f. 1–198.* Oxford: Clarendon Press.

Beijerinck, M. W. 1888. Die Bacterien der Papilionaceen-Knöllchen. Bot. Zeit. **46:** 725–735. *pl. 11.*

Bell, H. P. 1924. Fern rusts of *Abies*. Bot. Gaz. **77:** 1–31. *f. 1–10 + pl. 1–5.*

Biffen, R. H. 1907. Studies in inheritance of disease resistance. Jour. Agr. Sci. **2:** 109–128.

Blackman, V. H. 1904. On the fertilization, alternation of generations and general cytology of the Uredineae. Ann. Bot. **18:** 323–373. *pl. 21–24.*

———. 1924. Physiological aspects of parasitism. Proc. British Assoc. Bot. Toronto 233–246.

Blackman, V. H., & Welsford, E. J. 1916. Studies in the physiology of parasitism. Infection by *Botrytis cinerea*. Ann. Bot. **30:** 389–398. *f. 1, 2 + pl. 10.*

Bolley, H. L. 1906. Rust problems. North Dakota Agr. Exp. Sta. Bull. 68: 607–672. *f. 1–29.*

Boyle, C. 1921. Studies in the physiology of parasitism. VI. Infection by *Sclerotinia Libertiana.* Ann. Bot. **35:** 337–348. *pl. 14.*

Brefeld, O., & Istvánffi, G. 1895. Untersuchungen aus dem Gesammtgebiete der Mykologie. Heft XI. Die Brandpilze. II. Die Brandkrankheiten des Getreides. 1–98. *pl. 1–5.*

Brown, W. 1915. Studies in the physiology of parasitism. Action of *Botrytis cinerea.* Ann. Bot. **29:** 313–348.

Brierly, W. B. 1919. Some concepts in mycology; an attempt at synthesis. Trans. British Mycol. Soc. **6:** 204–235.

Buchanan, R. E. 1909. The bacteroids of *Bacillus radicicola.* Centralbl. Bakt. 2. Abt. **23:** 59–91. *f. 1–9.*

Butler, E. J. 1907. Some diseases of cereals caused by *Sclerospora graminicola.* India Dept. Agr. Mem. Bot. V. **2:** 1–24. *pl. 1–5.*

————. 1910. The bud-rot of palms in India. Mem. Dept. India. Bot. Ser. 3: 221–280. *f. 1 + pl. 1–5.*

————. 1911. The leaf spot of turmeric (*Taphrina maculans* sp. nov.). Ann. Mycol. **9:** 36–39. *f. A + pl. 4.*

————. 1918. Fungi and disease in plants. 1–547. Calcutta and Simla: Thacker, Spink & Co.

Burgeff, H. 1920. Ueber den Parasitismus des *Chaetocladium* und die heterocaryotische Natur der von ihm auf Mucorineen erzeugten Gallen. Zeitsch. Bot. **12:** 1–35. *f. 1–27.*

Carleton, M. A. 1899. Cereal rusts of the United States. U. S. Dept. Agr. Div. Veg. Phys. Path. Bull. 16: 1–73. *f. 1 + pl. 1–4.*

Clinton, G. P. 1897. Broom-corn smut. Univ. Illinois Agr. Exp. Sta. Bull. 47: 373–412. *pl. 1–5.*

————. 1904. Notes on fungous diseases, Asparagus. Conn. Agr. Exp. Sta. Ann. Rep. **28:** 313–315. *pl. 19.*

Clinton, G. P., & McCormick, F. A. 1916. Infection experiments of *Pinus Strobus* with *Cronartium ribicola.* Conn. Agr. Exp. Sta. Bull. 214: 428–459. *pl. 37-44.*

Colley, R. H. 1918. Parasitism, morphology, and cytology of *Cronartium ribicola.* Jour. Agr. Res. **15:** 619–659. *f. 1 + pl. 48–59.*

Comes, O. 1909. Del fagiuolo comune (*Phaseolus vulgaris* L.) Atti R. Ist. Incoragg. Napoli VI. **61:** 73–183.

Dawson, M. 1899. "Nitragin" and the nodules of Leguminous plants. Phil. Trans. Royal Soc. London B. **192:** 1–28. *pl. 1.*

Dey, P. K. 1919. Studies in physiology of parasitism. V. Infection by *Colletotrichum Lindemuthianum.* Ann. Bot. **33:** 305–312. *pl. 21.*

Dickson, J. G. 1923. Influence of soil temperature and moisture on the development of the seedling blight of wheat and corn caused by *Gibberella Saubinetii.* Jour. Agr. Res. **23:** 837–870. *f. 1–15 + pl. 1–3.*

Dickson, J. G., Eckerson, S. H., & Link, K. P. 1923. The nature of resistance to seedling blight of cereals. Proc. Nat. Acad. Sci. **9:** 434–439. *f. 1–4.*

Dodge, B. O. 1918. Studies in the genus *Gymnosporangium*. I. Brooklyn Bot. Gard. Mem. **1**: 128–140. *f. 1–6 + pl. 1.*

————. 1922. Studies in the genus *Gymnosporangium*. IV. Am. Jour. Bot. **9**: 354–365. *f. 1–7 + pl. 22.*

————. 1923a. Systemic infections of *Rubus* with the orange-rusts. Jour. Agr. Res. **25**: 209–242. *f. 1–5 + pl. 1–7.*

————. 1923b. Effect of the orange-rusts of *Rubus* on the development and distribution of stomata. Jour. Agr. Res. **25**: 495–500. *f. 1 + pl. 1.*

Dodge, B. O., & Adams, J. F. 1917. Some observations on the development of *Peridermium Cerebrum*. Mem. Torrey Club **17**: 253–261. *f. 1–3 + pl. 4–6.*

Doidge, E. M. 1920. South African Perisporiaceae. VI. The haustoria of the genera *Meliola* and *Irene*. Trans. Roy. Soc. South Africa **9**: 117–127. *f. 1–7.*

Doran, W. L. 1921. Rust of *Antirrhinum*. Mass. Agr. Exp. Sta. Bull. 202: 39–66. *pl. 1, 2.*

Ducomet, V. 1907. Rechérches sur le développement de quelques champignons parasites à thalle subcuticulaire. (Thèse) 1–275. *f. 1–33 + pl. 1–34.* Rennes: Guillemin et Voisin.

Duggar, B. M., & Stewart, F. C. 1901. The sterile fungus *Rhizoctonia* as a cause of plant diseases in America. Cornell Univ. Bot. Div. Agr. Exp. Sta. Bull. 186: 51–76. f. 15–23.

Eriksson, J., & Henning, E. 1896. Die Getreideroste. 1–463. *f. 1–5 + pl. 1–13.* Stockholm.

Evans, I. B. P. 1907. The cereal rusts. I. The development of their *Uredo* mycelia. Ann. Bot. **21**: 441–466. *pl. 40–43.*

Fischer von Waldheim, A. 1869. Beiträge zur Biologie und Entwickelungsgeschichte der Ustilagineen. Jahrb. Wiss. Bot. **7**: 61–144. *pl. 7–12.*

Frank, A. B. 1895. Die Krankheiten der Pflanzen **1**: 1–331. *f. 1–34.* Breslau: Trewendt.

Fromme, F. D. 1913. The culture of cereal rusts in the greenhouse. Bull. Torrey Club **40**: 501–521.

————. 1914. Morphology and cytology of the aecidium cup. Bot. Gaz. **58**: 1–35. *f. 1–8 + pl. 1, 2.*

Fromme, F. D., & Wingard, S. A. 1918. Bean rust: its control through the use of resistant varieties. Virginia Agr. Exp. Sta. Bull. 220: 1–18. *pl. 1–5.*

Galloway, B. T. 1896. A rust and leaf casting of pine leaves. Bot. Gaz. **22**: 433–453. *f. 1–3 + pl. 22, 23.*

Gassner, G. 1922. Ueber einen eigenartigen *Uromyces* auf *Passiflora foetida* L. Ber. Deutsch. Bot. Gesell. **40**: 64–68. *f. 1–3.*

Gibson, C. M. 1904. Notes on infection experiments with various Uredineae. New Phytologist **3**: 184–191. *pl. 5, 6.*

Groom, P. 1895. On *Thismia Aseroe* (Beccari) and its mycorrhiza. Ann. Bot. **9**: 327–360. *pl. 13, 14.*

Guttenberg, H., Ritter von. 1905. Beiträge zur physiologischen Anatomie der Pilzgallen. 1–70. *pl. 1–4.* Leipzig: Engelmann.

Halsted, B. D. 1898. Starch distribution as affected by fungi. Proc. Am. Assoc. Adv. Sci. **47:** 408–409.

Hansteen-Cranner, B. 1922. Zur Biochemie und Physiologie der Grenzschichten lebender Pflanzenzellen. Meldinger fra Norges Landbrugshöiskole **2:** 1–160. *pl. 1–17.*

Harper, R. A. 1896. Ueber das Verhalten der Kerne bei der Fruchtenwickelung einiger Ascomyceten. Jahrb. Wiss. Bot. **29:** 654–685. *pl. 11, 12.*

Hart, H. 1926. Factors affecting the development of flax rust, *Melampsora Lini.* Phytopathology **16:** 185–205. *f. 1, 2.*

Hartig, R. 1882. Lehrbuch der Baumkrankheiten. 1–198. *f. 1–86* + *pl. 1–11.* Berlin: Springer.

————. 1884. Ein neuer Parasit der Weisstanne. *Trichosphaeria parasitica* n. sp. Allg. Forst- und Jagdzeit. **60:** 1–14. *f. 1–6.*

————. 1892. *Septogloeum Hartigianum* Sacc. Ein neuer Parasit des Feldahornes. Forstl. Naturwiss. Zeitschr. **1:** 289–291. *f. 1.*

Hawkins, L. A., & Harvey, R. B. 1919. Physiological study of parasitism of *Pythium debaryanum* Hesse on potato tubers. Jour. Agr. Res. **18:** 275–297. *f. 1, 2.*

Higgins, B. B. 1914a. *Cylindrosporium* on stone fruits. Am. Jour. Bot. **1:** 145–173. *pl. 13–16.*

————. 1914b. Life history of a new species of *Sphaerella.* Mycol. Centralbl. **4:** 187–193. *f. 1, 2.*

Holbert, J. R., & Koehler, B. 1924. Anchorage and extent of corn root systems. Jour. Agr. Res. **27:** 71–78. *f. 1* + *pl. 1–5.*

Holden, R. J., & Harper, R. A. 1903. Nuclear divisions and nuclear fusion in *Coleosporium Sonchi-arvensis* Lev. Trans. Wisconsin Acad. Sci. Arts and Letters **14:** 63–82. *pl. 1, 2.*

Hopkins, E. F. 1921. The *Botrytis* blight of tulips. Cornell Univ. Agr. Exp. Sta. Mem. 45: 315–361. *f. 22–50* + *pl. 33.*

Hursh, C. R. 1924. Morphological and physiological studies on the resistance of wheat to *Puccinia graminis Tritici* Erikss. and Henn. Jour. Agr. Res. **27:** 381–412. *f. 1* + *pl. 1, 2.*

Istvánffi, G. de, & Palinkás, G. 1913. Études sur le mildiou de la vigne. Ann. Inst. Centr. Ampélologique Hongrois **4:** 1–125. *f. 1, 2* + *pl. 1–9.*

Jones, F. R., & Drechsler, C. 1920. Crownwart of alfalfa caused by *Urophlyctis Alfalfae.* Jour. Agr. Res. **20:** 295–324. *pl. 47–56.*

Jones, L. R., Giddings, N. J., & Lutman, B. F. 1912. Investigations of the potato fungus, *Phytophthora infestans.* U. S. Dept. Agr. Bur. Pl. Ind. Bull. 245: 1–100. *f. 1–10* + *pl. 1–10.*

Klebahn, H. 1896. Kulturversuche mit heteroecischen Rostpilzen. Zeitschr. Pflanzenkr. **6:** 262–270. *f. 1–3.*

————. 1909. Krankheiten des Flieders. 75 pp. *45 fig.* Berlin: Bornträger.

————. 1912. Grundzüge der allgemeinen Phytopathologie. 1–147. *f. 1–74.* Berlin: Bornträger.

Knowles, E. L. 1889. Study of abnormal structures induced by *Ustilago Zeae-Maydis.* Jour. Mycol. **5:** 14–18. *pl. 2–7.*

Kunkel, L. O. 1915. Contributions to the life history of *Spongospora subterranea*. Jour. Agr. Res. **4**: 265–278. *pl. 39–43.*

————. 1918. Tissue invasion by *Plasmodiophora Brassicae*. Jour. Agr. Res. **14**: 543–572. *f. 1, 2 + pl. 61–80.*

Kursanov, L. I. 1917. Recherches morphologiques et cytologiques sur les Uredinées. Bull. Soc. Imp. Natural. Moscou II. **31**: 1–129.

Lang, W. H. 1899. The prothallus of *Lycopodium clavatum*, L. Ann. Bot. **13**: 277–317. *pl. 16, 17.*

Leitgeb, M. H. 1881. *Completoria complens* Lohde, ein in Farnprothallien schmarotzender Pilz. Sitzungsber. Akad. Wiss. Wien. Math. Nat. Cl. **84**^{1}: 288–324. *1 pl.*

Long, F. L. 1919. The quantitative determination of photosynthetic activity in plants. Physiol. Res. **2**: 277–300.

Lüdi, R. 1901. Beiträge zur Kenntniss der Chytridiaceen. Hedwigia **40**: 1–44. *pl. 1, 2.*

Lutman, B. F. 1910. Some contributions to the life history and cytology of the smuts. Trans. Wisconsin Acad. **16**: 1191–1228. *pl. 88–95.*

————. 1913. Studies on club-root. I. The relation of *Plasmodiophora Brassicae* to its host and the structure and growth of its plasmodium. Vermont Agr. Exp. Sta. Bull. 175: 1–27. *f. 1–6 + pl. 1–4.*

Magnus, P. 1896. Eine nordamerikanische Ustilaginee auf *Panicum Crus-galli*. Ber. Deutsch. Bot. Gesell. **14**: 216–221. *pl. 15.*

————. 1897. Ueber das Mycelium des *Aecidium Magellanicum* Berk Ber. Deutsch. Bot. Gesell. **15**: 148–152. *pl. 4.*

Magnus, W. 1900. Studien an der endotrophen Mykorrhiza von *Neottia Nidus-avis* L. Jahrb. Wiss. Bot. **35**: 205–272. *pl. 4–6.*

Mains, E. B. 1917. The relation of some rusts to the physiology of their hosts. Am. Jour. Bot. **4**: 179–220. *pl. 4, 5.*

Maire, R. 1908. Les sucoirs des *Meliola* et des *Asterina*. Ann. Mycol. **6**: 124–128. *f. 1–4.*

Mangin, L. 1895. Recherches anatomiques sur les Péronosporées. Bull. Soc. Hist. Nat. Autun **8**: 55–108. *f. 1–12 + pl. 10, 11.*

Marryat, D. C. E. 1907. Notes on infections and histology of two wheats immune to attacks of *Puccinia glumarum*. Jour. Agr. Sci. **2**: 129–138. *pl. 2.*

Massee, G. E. 1899. A text book of plant diseases. 1–458. *f. 1–91.* London: Duckworth & Co.

Meehan, T. 1899. On the influence of fungi on form and character of plants. Proc. Acad. Nat. Sci. Phila. **51**: 108–110. *f. 1.*

Meyer, Arthur. 1918. Eiweisstoffwechsel und Vergilben der Laubblätter von *Tropaeolum majus*. Flora **111–112**: 85–127. *f. 1–17.*

Mohl, H. von. 1853. Ueber die Traubenkrankheiten. Bot. Zeit. **11**: 585–595. *pl. 11.*

Morgenthaler, O. 1910. Ueber die Bedingungen des Teleutosporenbildung bei den Uredineen. Centralbl. Bakt. 2 Abt. **27**: 73–93. *f. 1–18.*

Moss, E. H. 1926. The uredo stage of the Pucciniastreae. Ann. Bot. **40**: 813–847. *f. 1–21 + pl. 34.*

Müller, W. 1908. Der Entwickelungsgang des *Endophyllum Euphorbiae silvaticae* (DC) Winter und der Einfluss dieses Pilzes auf die Anatomie seiner Nährpflanze *Euph. Amygdaloides.* Centralbl. Bakt. 2 Abt. **20:** 333–341.

Nawaschin, S. 1899. Beobachtungen über den feineren Bau und Umwandlungen von *Plasmodiophora Brassicae* Woron. im Laufe ihres intracellularen Lebens. Flora **86:** 404–427. *pl. 20.*

Nemec, B. 1904. Ueber die Mykorrhiza bei *Calypogeia Trichomanis.* Beihefte Bot. Centralb. **16:** 253–268. *pl. 12.*

————. 1911. Zur Kenntniss der niederen Pilze. II. Die Haustorien von *Uromyces Betae* Pers. Bull. Internat. Acad. Sci. Bohême **16:** 1–10. *1 pl.*

Nicolas, G. 1920. Sur la respiration des plantes parasitées par des champignons. Compt. Rend. Acad. Sci. Paris **170:** 750–752.

Nobbe, F., & Hiltner, L. 1900. Künstliche Ueberfuhrung der Knollchenbakterien von Erbsen in solche von Bohnen (*Phaseolus*). Centralbl. Bakt. 2 Abt. **6:** 449–457. *1 pl.*

Olive, E. W. 1918. Cytological structure of *Botryorrhiza Hippocrateae.* Mem. Brooklyn Bot. Gard. **1:** 337–341. *pl. 8.*

Osborn, T. G. B. 1911. *Spongospora subterranea* (Wallroth) Johnson. Ann. Bot. **25:** 327–339. *pl. 27.*

Osner, G. A. 1916. Leaf Smut of Timothy. Cornell Univ. Agr. Exp. Sta. Bull. 381: 186–230. *f. 45–58 + pl. 17.*

Overholts, L. O. 1926. Mycological notes for 1924. Mycologia **18:** 35.

Peirce, G. J. 1902. The root-tubercles of Bur Clover (*Medicago denticulata* Willd.) and of some other leguminous plants. Proc. Calif. Acad. Sci. Bot. III. **2:** 295–328. *pl. 29.*

Peltier, G. L. 1916. Parasitic Rhizoctonias in America. Illinois Agr. Exp. Sta. Bull. 189: 283–390. *f. 1–24.*

————. 1923. A study of the environmental conditions influencing the development of stem rust in the absence of an alternate host. II. Infection studies with *P. graminis Tritici* form 3 and form 9. Univ. Nebraska Agr. Exp. Sta. Res. Bull. 25: 1–52. *pl. 1–12.*

Pritchard, F. J. 1911. The wintering of *Puccinia graminis Tritici* E. & H. and the infection of wheat thru the seed. Phytopathology **1:** 150–154. *f. 1, 2 + pl. 22.*

Raines, M. A. 1922. Vegetative vigor of the host as a factor influencing susceptibility and resistance to certain rust diseases of the higher plants. Am. Jour. Bot. **9:** 183–203; 215–238. *pl. 11, 12.*

Reed, G. M. 1918. Physiological specialization of parasitic fungi. Brooklyn Bot. Gard. Mem. **1:** 348–409.

Reed, H. S., & Crabill, C. H. 1915. Cedar rust disease of apples caused by *Gymnosporangium Juniperi-virginianae* Schw. Virginia Poly. Inst. Va. Agr. Exp. Sta. Tech. Bull. 9: 1–106. *f. 1–23.*

Reynolds, E. S. 1912. Studies of parasitized leaf tissue. Bot. Gaz. **53:** 365–395. *f. 1–9.*

Rice, M. A. 1924. Internal sori of *Puccinia Sorghi.* Bull. Torrey Club **51:** 37–50. *f. 1–4.*

Richards, H. M. 1896. On some points in development of aecidia. Proc. Am. Acad. Arts and Sci. **31:** 255–270. *1 pl.*

Riker, A. J. 1923. Some relations of the crowngall organism to its host tissue. Jour. Agr. Res. **25:** 119–132. *pl. 1–5.*

Rolfs, F. M. 1904. Potato failures. Colorado Agr. Exp. Sta. Bull. 91: 1–33. *pl. 1–5.*

Rosen, F. 1893. Beiträge zur Kenntniss der Pflanzenzellen Studien über die Kerne und die Membren bildung bei Mykomyceten und pilzen. II. Beitr. Biol. Pflanzen **6:** 237–266. *pl. 2, 3.*

Salmon, E. S. 1905. On the stages of development reached by certain biologic forms of *Erysiphe* in cases of non-infection. New Phytologist **4:** 217–221. *pl. 5.*

Sappin-Trouffy [, F. P. S.] 1896a. Recherches mycologiques. Le Botaniste **5:** 44–58. *f. 1–6.*

————. 1896b. Recherches histologiques sur la famille des Urédinées. Le Botaniste **5:** 59–244. *f. 1–70.*

Sartoris, G. B. 1924. Studies in the life history and physiology of certain smuts. Am. Jour. Bot. **11:** 617–646. *pl. 39–41.*

Seaver, F. J., & Horne, W. T. 1917. Life-history studies in *Sclerotinia.* Mem. Torrey Club **17:** 202–206. *pl. 3.*

Schroeter, J. 1875. Entwicklungsgeschichte einiger Rostpilze. Beitr. Biol. Pflanzen **1**^{3}**:** 1–10.

Smith, G. 1900. The haustoria of the Erysipheae. Bot. Gaz. **29:** 153–184. *pl. 11, 12.*

Smith, R. E. 1905. Asparagus and asparagus rust in California. Univ. Calif. Agr. Exp. Sta. Bull. 165: 1–100. *f. 1–46.*

Smith, T. 1921. Parasitism as a factor in disease. Science **54:** 99–108.

Stakman, E. C. 1914. A study in cereal rusts, physiological races. Univ. Minnesota Agr. Exp. Sta. Bull. 138: 1–56. *pl. 1–9.*

————. 1915. Relation between *Puccinia graminis* and plants highly resistant to its attack. Jour. Agr. Res. **4:** 193–200. *pl. 28.*

Stakman, E. C., & Aamodt, O. S. 1924. The effect of fertilizers on the development of stem rust of wheat. Jour. Agr. Res. **27:** 341–379. *f. 1, 2 + pl. 1–3.*

Stämpfli, R. 1910. Untersuchungen über die Deformationen, welche bei einigen Pflanzen durch Uredineen hervorgerufen werden. Hedwigia **49:** 230–267. *f. 1–27.*

Stevens, F. L., & Hall, J. G. 1910. Diseases of economic plants. 1–513. *f. 1–219.* New York: Macmillan & Co.

Stevens, N. R., & Hawkins, L. A. 1917. Some changes produced in strawberry fruits by *Rhizopus nigricans.* Phytopathology **7:** 178–184.

Stevens, W. C. 1916. Plant Anatomy, 3d. ed. 1–319, *f. 1–155.* Philadelphia.

Stewart, A. 1915. An anatomical study of *Gymnosporangium* galls. Am. Jour. Bot. **2:** 402–417. *f. 1 + pl. 15, 16.*

Thurston, H. W. 1923. Intermingling gametophytic and sporophytic mycelium in *Gymnosporangium bermudianum.* Bot. Gaz. **75:** 225–248. *f. 1–4 + pl. 12, 13.*

Thomas, H. E. 1921. The relation of the health of the host and other factors to infection of *Apium graveolens* by *Septoria Apii.* Bull. Torrey Club **48:** 1–29.

Tieghem, P. van, & Le Monnier, G. 1873. Recherches sur les Mucorinées. Ann. Sci. Nat. Bot. V. **17:** 269–399. *pl. 20–25.*

Tischler, G. 1911. Untersuchungen über die Beeinflussung der *Euphorbia Cyparissias* durch *Uromyces Pisi.* Flora **104:** 1–60. *f. 1–26.*

Tisdale, W. H. 1919. *Physoderma* disease of corn. Jour. Agr. Res. **16:** 137–154. *f. 1 + pl. A, B, 10–17.*

Tubeuf, K. F. von. 1897. Diseases of plants. Transl. by W. G. Smith. London: Longmans, Green & Co.

Vuillemin, P. 1894. Les Puccinies des *Thesium.* Bull. Soc. Mycol. France **10:** 107–128.

Ward, H. M. 1882. On the morphology of *Hemileia vastatrix* Berk. & Br. Quart. Jour. Micr. Sci. **22:** 1–11. *pl. 1–3.*

————. 1888. A lily disease. Ann. Bot. **2:** 319–382. pl. 20–24.

————. 1890. Croonian Lecture.—On some relations between host and parasite in certain epidemic diseases of plants. Proc. Roy. Soc. London **47:** 393–443. *f. 1–16.*

————. 1901. Disease in plants. 1–309. London: Macmillan & Co.

————. 1902a. On pure cultures of a Uredine, *Puccinia dispersa* (Eriks.). Proc. Roy. Soc. London **69:** 451–466. *f. 1, 2.*

————. 1902b. On the relations between host and parasite in the bromes and their brown rust, *Puccinia dispersa* (Eriks.). Ann. Bot. **16:** 233–315.

————. 1904. On the histology of *Uredo dispersa* Eriks. and the mycoplasm hypothesis. Phil. Trans. Roy. Soc. London Ser. B **196:** 29–46. *pl. 4–6.*

————. 1905. Recent researches on the parasitism of fungi. Ann. Bot. **19:** 1–54.

Waterhouse, W. L. 1921. Studies in the physiology of parasitism. VII. Infection of *Berberis vulgaris* by sporidia of *Puccinia graminis.* Ann. Bot. **35:** 557–564. *f. 1–19.*

Weber, G. F. 1922. Studies on corn rust. Phytopathology **12:** 89–97. *f. 1–3.*

Weimer, J. L., & Harter, L. I. 1921. Respiration and carbohydrate changes produced in sweet potatoes by *Rhizopus tritici.* Jour. Agr. Res. **21:** 627–635.

Weiss, F. 1924. The effect of rust infection upon the water requirement of wheat. Jour. Agr. Res. **27:** 107–118.

Weston, Wm. H., Jr. 1920. Philippine downy mildew of maize. Jour. Agr. Res. **19:** 97–122. *pl. A, B, 16–25.*

Whetzel, H. H. 1904. *Peronospora Schleideniana.* Cornell Univ. Agr. Exp. Sta. Bull. 218: 134–161. *f. 1–17.*

Whetzel, H. H., Jackson, H. S., & Mains, E. B. 1925. The composite life history of *Puccinia Podophylli* Schw. Jour. Agr. Res. **30:** 65–79. *pl. 1–4.*

Whitehead, T. 1921. On the life history and morphology of *Urocystis Cepulae.* Brit. Myc. Soc. Trans. **7:** 65–71. *pl. 2.*

Wisselingh, C. van. 1898. Microchemische Untersuchungen über die Zellwände der Fungi. Jahrb. Wiss. Bot. **31**: 619–687. *pl. 17, 18.*

Wolf, F. A. 1924. Bacterial pustule of soybean. Jour. Agr. Res. **29**: 57–68. *f. 1–4 + pl. 1–3.*

Wolff, R. 1873. Beitrag zur Kenntniss der Ustilagineen. Bot. Zeit. **31**: 673–677.

Zach, F. 1910. Cytologische Untersuchungen an den Rostflecken des Getreides und die Mycoplasmatheorie J. Eriksson's. Sitzb. Akad. Wien Mat. Nat. Kl. **119**^{1}: 307–330. *pl. 1, 2.*

Zender, J. 1924. Les haustoriums de la Cuscute et les réactions de l'hôte. Univ. Genève-Inst. Bot. X^{me} Ser. Fasc. **8**: 1–81. *f. 1–50 + pl. 1–3.*

Description of plates

The figures of PLATES 1 to 9, with the exception of FIG. 1, were drawn with the aid of a camera lucida from sections 5–7.5 microns thick. A Leitz microscope was used with a 1/16 inch oil immersion objective and an ocular 2. Unless otherwise stated, the material was fixed in Flemming's medium solution, and stained in Flemming's triple stain. FIG. 1 was drawn with the aid of a camera lucida from a strip of epidermis with Leitz objective 7 and ocular 3. FIG. 1 is magnified approximately 750 times; the other figures, approximately 1200 times. The figures of PLATES 8 and 9 are free-hand drawings made from living plants; they were drawn actual size, but have been reduced in reproduction.

PLATE 1

Early stages of infection of corn tissue with Puccinia Sorghi

FIG. 1. A germ tube of *Puccinia Sorghi* at a stoma. The preparation was mounted in lacto-phenol and stained with Coton Bleu.

FIG. 2. Intercellular hyphae and an appressorium containing two nuclei.

FIG. 3. Haustorium mother cell in contact with an epidermal cell sending papilla into the cell.

FIG. 4. Slightly later stage of a penetration filament. a. View at lower focal plane. b. View at upper focal plane.

FIG. 5. Portion of an epidermal cell showing young haustorium and mother cell.

FIG. 6. Young haustorium showing a deeply stained center and two deeply stained granules in the stalk.

FIG. 7. Young haustorium showing the beginning of lobing in terminal knob.

FIGS. 8, 9. Later stages of lobed haustoria. (The stalk in figure 9 should be as distinct as that in figure 8.)

FIG. 10. A lobed haustorium in an epidermal cell arising from a branched hypha.

FIG. 11. A haustorium in contact with the nucleus of a mesophyll cell. The conjugate nuclei of the haustorium mother cell are clearly defined.

FIG. 12. A lobed haustorium in contact with the host cell nucleus of a mesophyll cell.

FIG. 13. A mature lobed haustorium in a mesophyll cell, showing conjugate nuclei in the lobe which indents the host cell nucleus.

PLATE 2

Puccinia Sorghi

FIGS. 14–18. The material was fixed in Carnoy's solution and stained with Flemming's triple stain. The section was cut longitudinally.

FIG. 14. Two mesophyll cells, each containing a lobed haustorium with slightly thickened stalks.

FIGS. 15, 16. Mesophyll cells containing haustoria showing variations in stalk development.

FIG. 17. Portion of an epidermal cell showing a haustorium with a thickening halfway up the slender stalk. (What appears to be a dash at the tip of the haustorium was not present in the original drawing.)

FIG. 18. Portion of a mesophyll cell containing a haustorium with a thickened stalk.

FIGS. 19, 20. Older stages of the rust taken from a green leaf bearing erumpent sori lying in yellow areas.

FIGS. 21–23. Cells from tangential section of 'green island' tissue, fixed in 50 per cent alcohol.

PLATE 3

Puccinia Sorghi

Late stages of infection from leaves with erumpent sori surrounded by yellow spots in a green leaf.

FIGS. 24, 25. Lobed haustoria arising from thickened bases and extending in direction of the long axis of the cell.

FIGS. 26–29. Haustoria in epidermal cells showing various degrees of sheathing.

FIG. 30. A mesophyll cell showing two haustoria with elongated lobes arising from thickened stalks.

FIG. 31. A cell just below a uredosorus containing two haustoria arising from spore bearing hyphae.

FIGS. 32–34. Cells showing heavy-walled haustoria from leaves of Golden Bantam corn.

PLATE 4

Puccinia Sorghi

FIG. 35. Hypertrophied, infected cell from a green leaf sheath near a uredosorus.

FIG. 36. An uninfected cell from the same tissue.

FIG. 37. A thick-walled haustorium in a thick-walled cell from the parenchyma tissue of a young corn cob.

FIG. 38. An encased haustorium from a thick-walled cell near a teleutosorus on a leaf sheath.

FIG. 39. Hypertrophied infected cell from a yellowed leaf sheath near a teleutosorus.

FIG. 40. Portion of an infected parenchyma cell near a teleutosorus upon the midrib of a leaf.

PLATE 5

Puccinia Sorghi

Cells from a leaf of outdoor corn, fixed in 50 per cent alcohol.

FIGS. 41–43. Mesophyll cells near the green edge of leaf, showing heavy infection but little sheathing of haustoria. (Figure 44, right, center, should be figure 42.)

FIGS. 44–47. Mesophyll cells from the yellowed area of the section, showing haustoria with various degrees of sheathing.

PLATE 6

Puccinia claytoniata, *P. Violae*, *Aecidium punctatum*, *Puccinia asterum*, *Uromyces appendiculatus*, *Uromyces houstoniatus*, *Uromyces caladii*

FIGS. 48, 49. Portions of cells from leaf of *Claytonia virginiana* infected with *Puccinia claytoniata.*

FIGS. 50, 51. Cells of *Viola cucullata* infected with *Puccinia Violae.*

FIG. 52. Cell from a leaf of *Hepatica acutiloba* infected with *Aecidium punctatum.*

FIG. 53. Cell from a leaf of *Solidago* sp. infected with *Puccinia asterum.*

FIG. 54. Portion of a cell from leaf of Kentucky Wonder Bean infected with *Uromyces appendiculatus.*

FIG. 55. Portion of a cell from leaf of *Houstonia caerulea* infected with *Uromyces houstoniatus.*

FIG. 56. A cell just beneath the epidermis of a spadix of *Arisaema triphyllum* which bore erumpent spermogonia of *Uromyces Caladii.*

PLATE 7

Aecidium Sambuci, *Chrysomyxa Pyrolae*

FIGS. 57. 58. Cells from a leaf gall of *Sambucus canadensis* infected with *Aecidium Sambuci.*

FIGS. 59, 60. Cells from a uredo-bearing leaf of *Pyrola americana* infected with *Chrysomyxa Pyrolae.*

FIGS. 61–64. Cells from teteuto-bearing leaves of *Pyrola americana* infected with *Chrysomyxa Pyrolae.*

PLATES 8 AND 9

Puccinia Sorghi

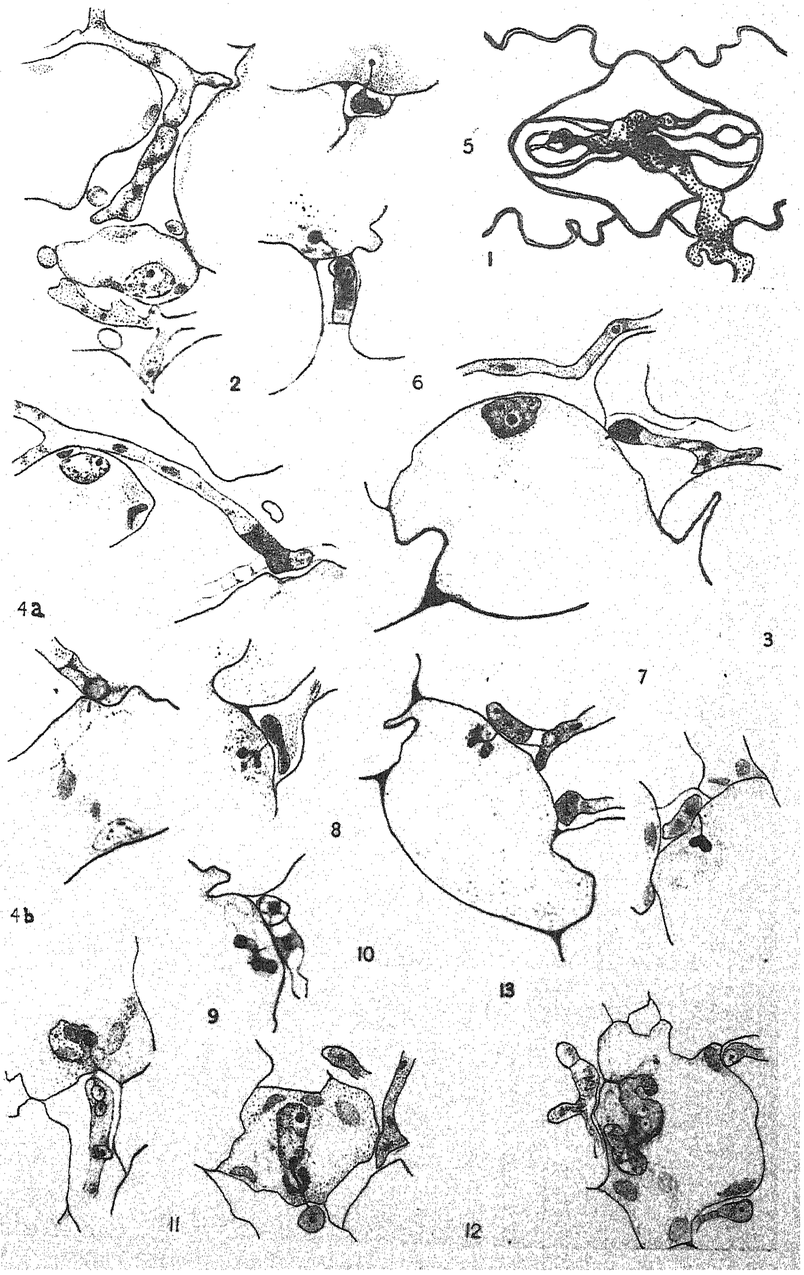
Leaves exhibiting typical stages of infection with *Puccinia Sorghi* found in a field of Golden Bantam corn; they show the color effects of infected areas of leaves of varying age and varying degrees of infection.

FIG. 65. Pale green infection areas; a moderate infection in a vigorous leaf.

FIG. 66. Dead infection areas; a heavy infection in a vigorous leaf.

FIG. 67. Green infection areas in a dying leaf.

FIGS. 68–70. Green infection areas in dry basal leaves.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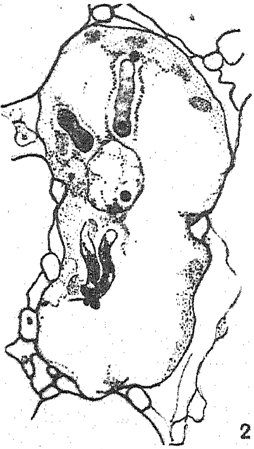

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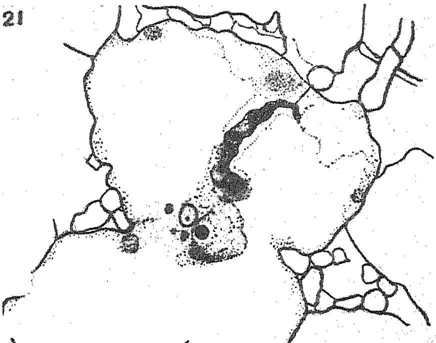

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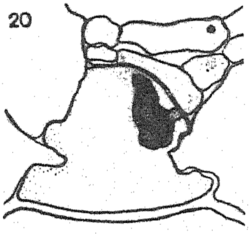

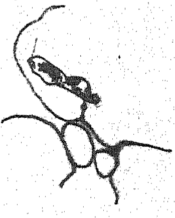

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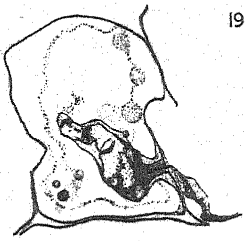

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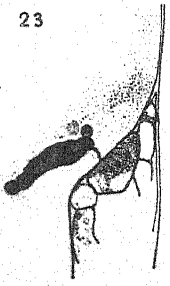

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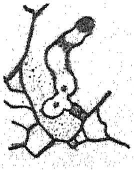

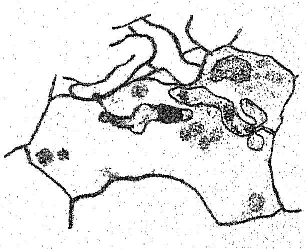

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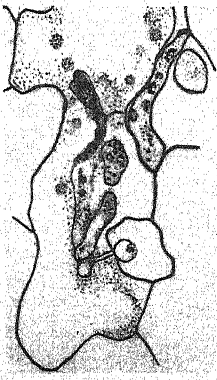

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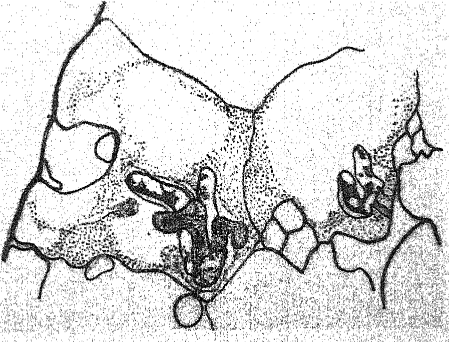

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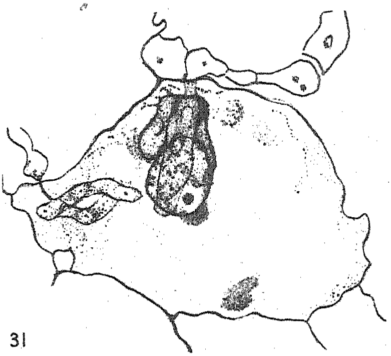
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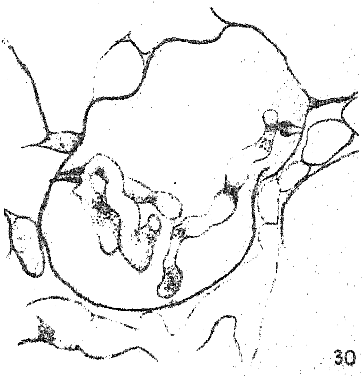
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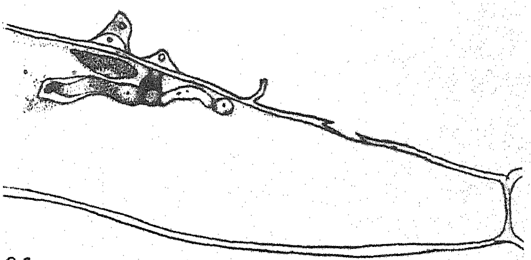
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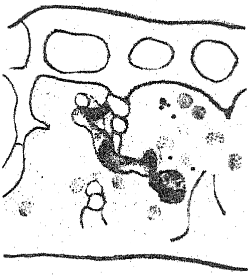
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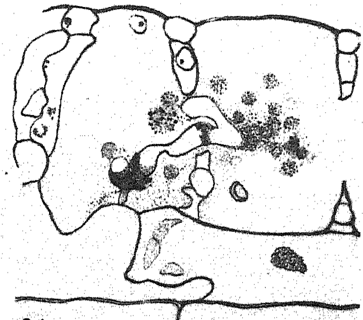
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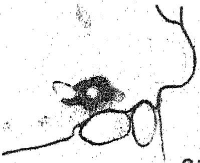
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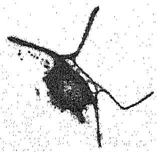
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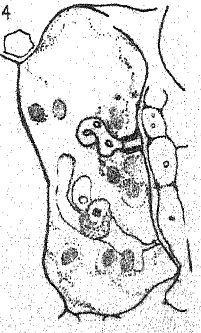
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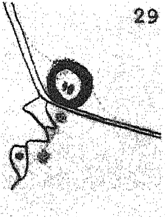
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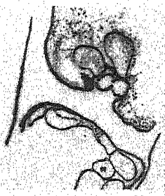
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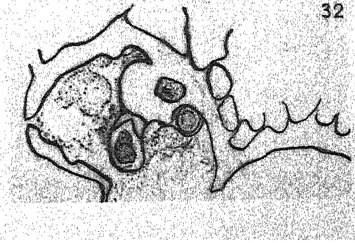
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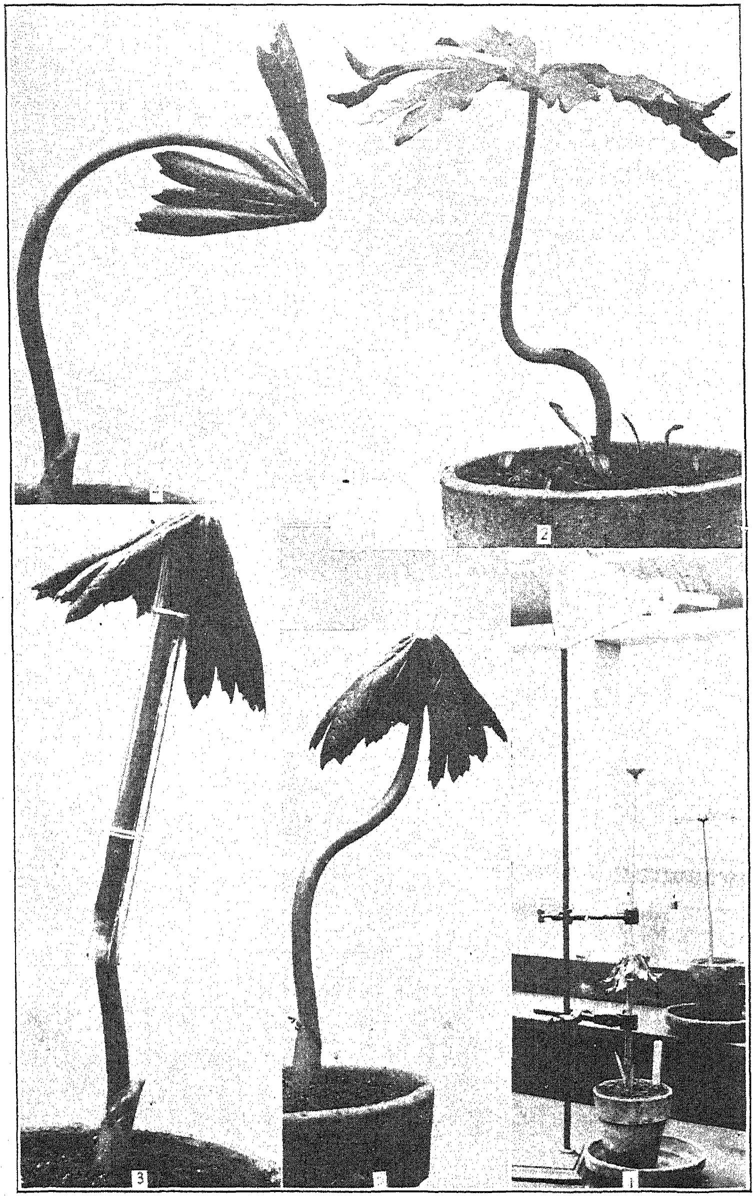

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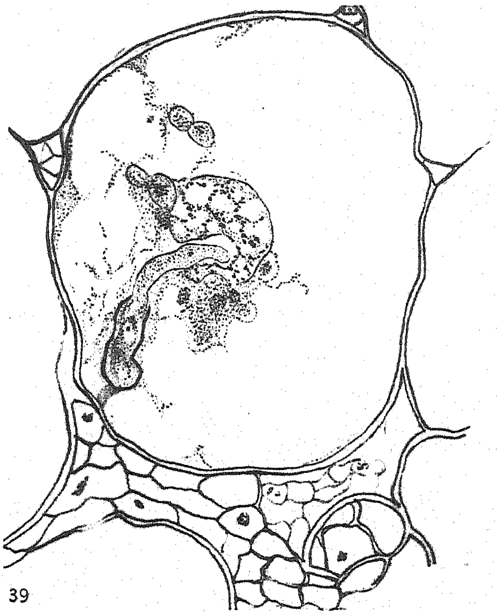

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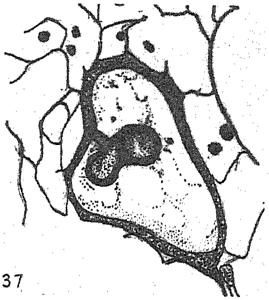

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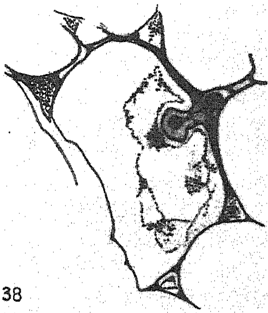

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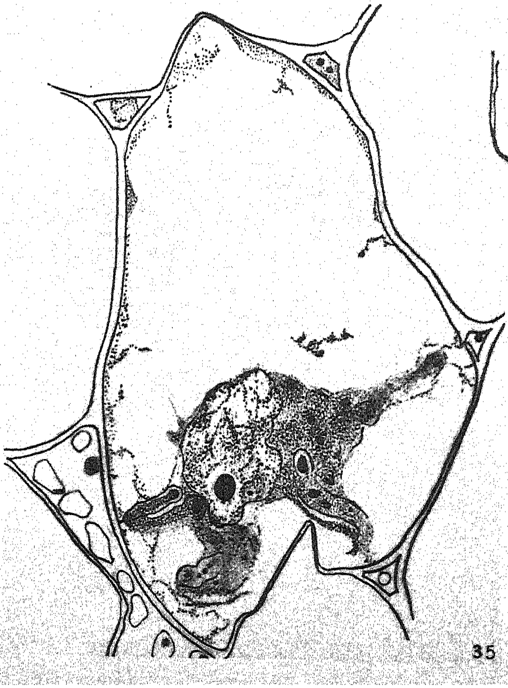

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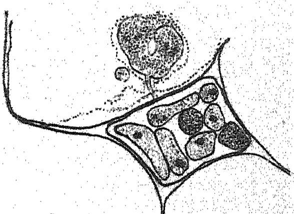

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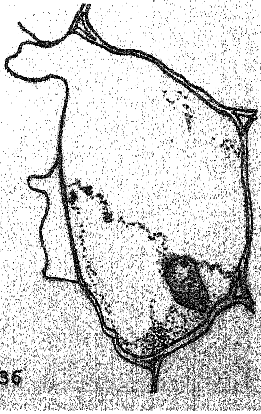

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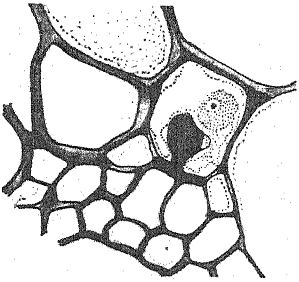

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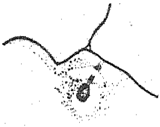

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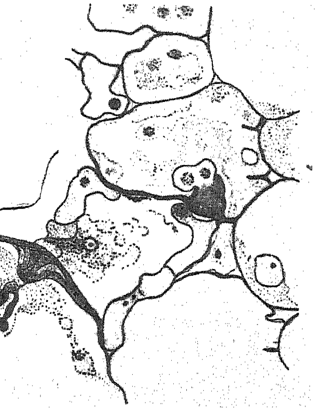

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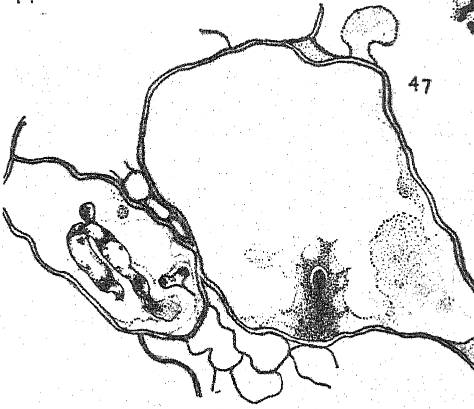

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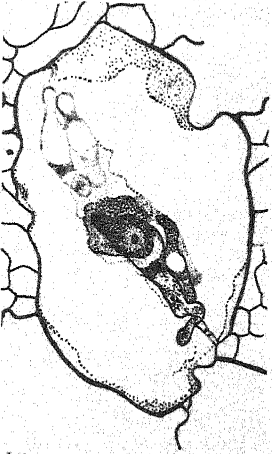

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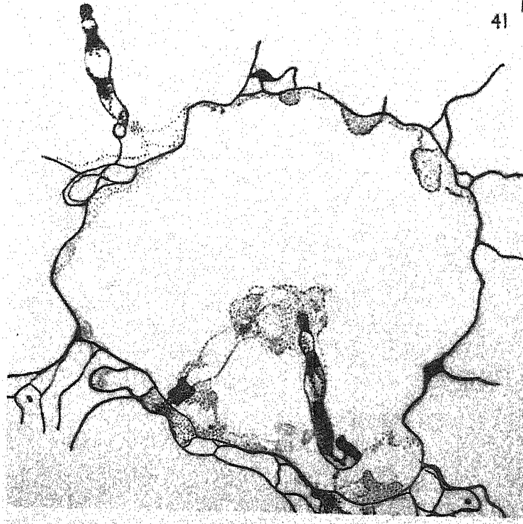

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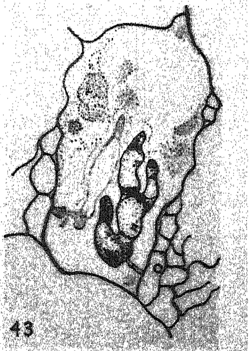

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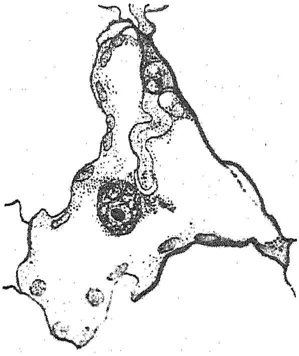

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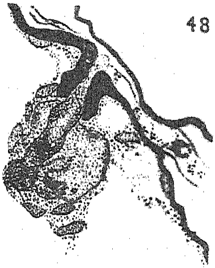

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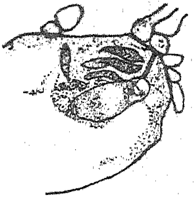

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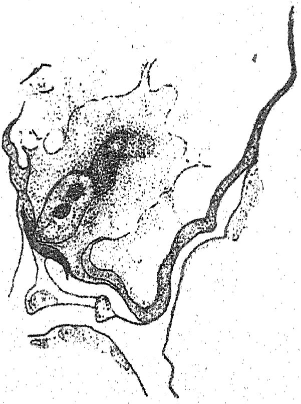

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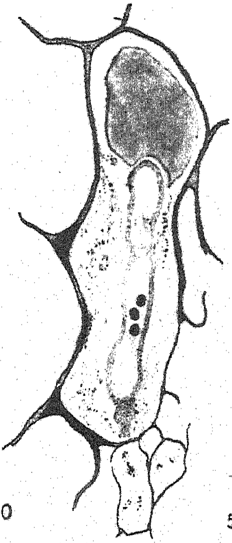

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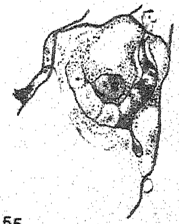

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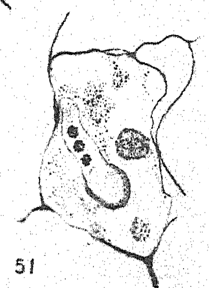

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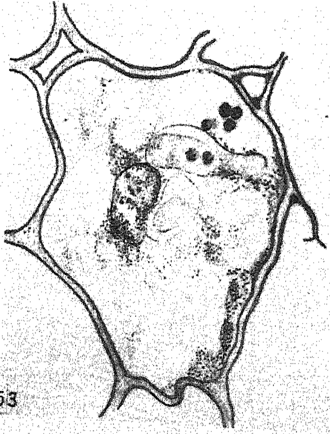

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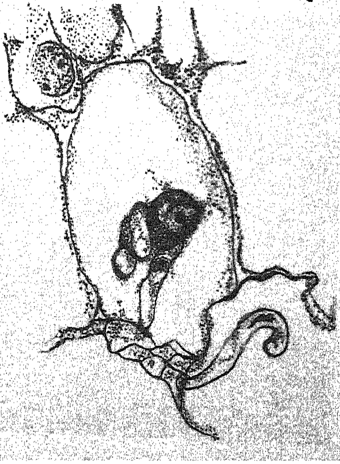

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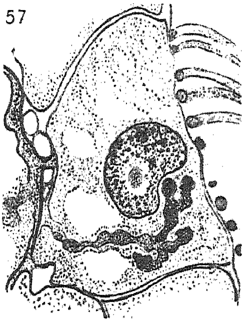

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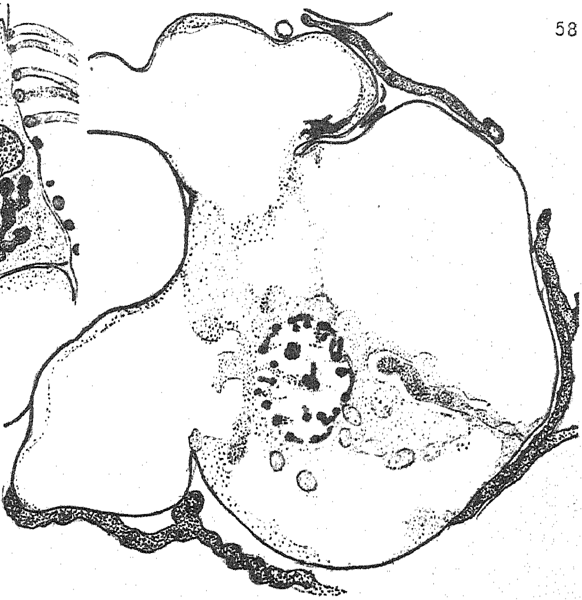

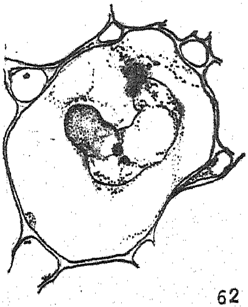

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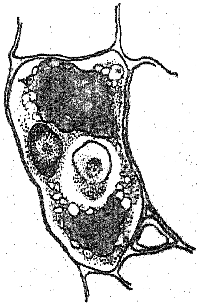

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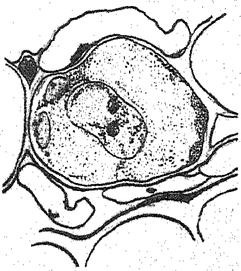

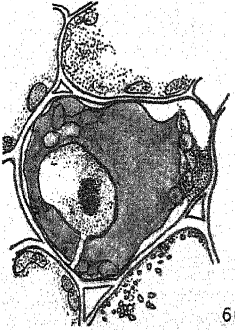

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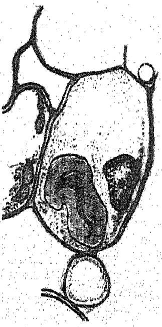

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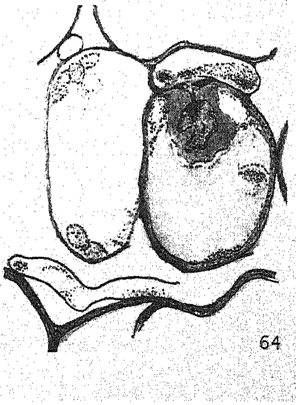

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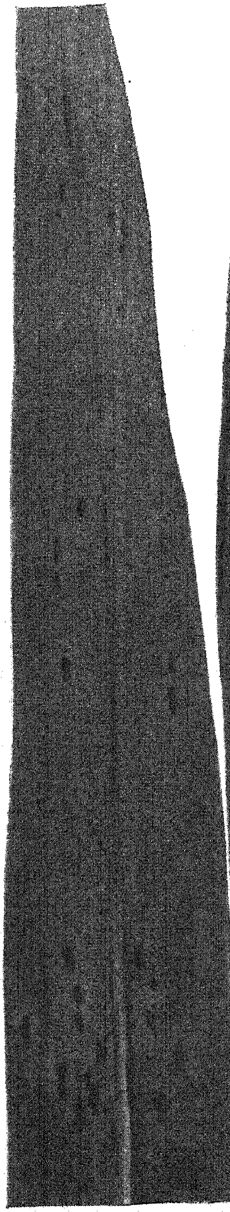

FIG. 65.

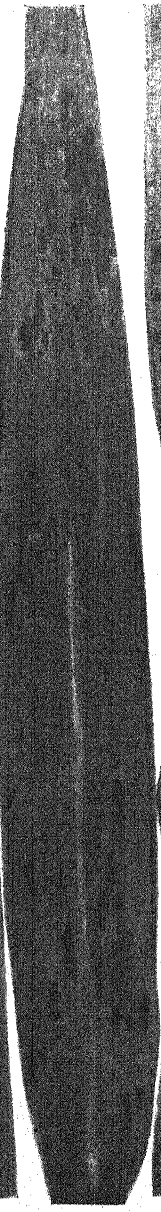

FIG. 66.

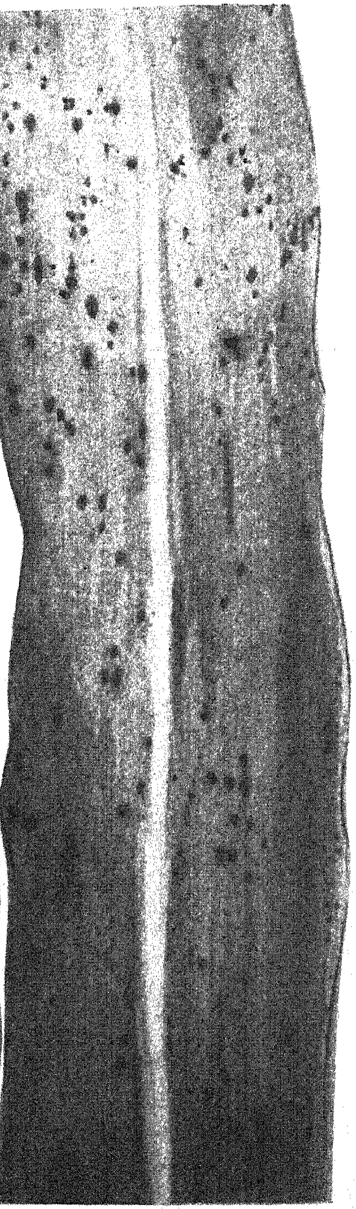

FIG. 67.

PUCCINIA SORGHI ON GOLDEN BANTAM CORN

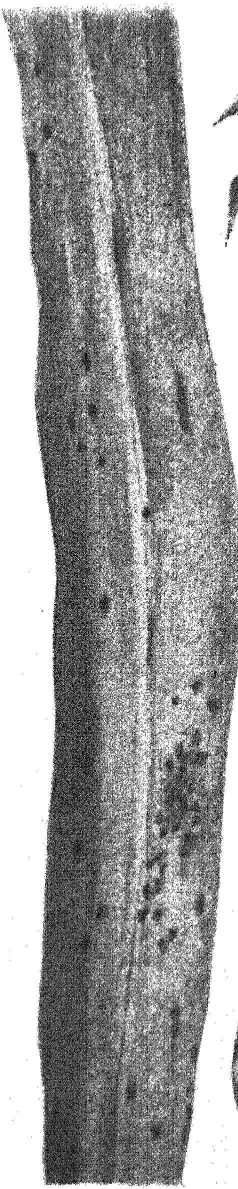

FIG. 68.

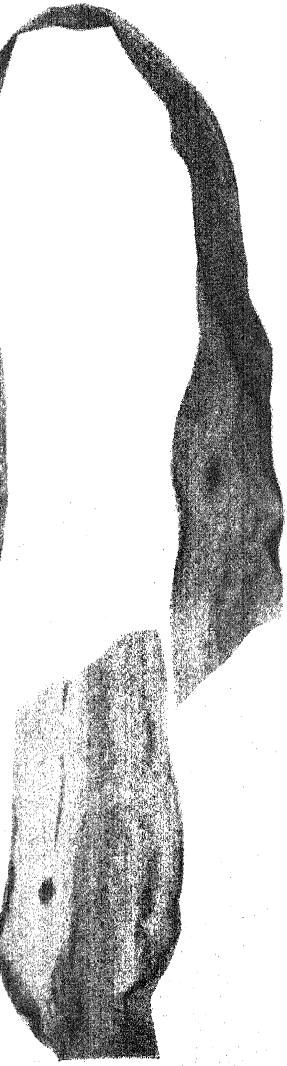

FIG. 70.

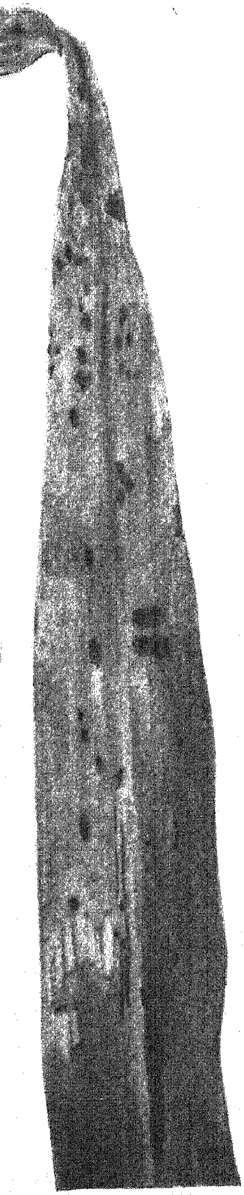

FIG. 69.

PUCCINIA SORGHI ON GOLDEN BANTAM CORN

Some ecological habitats in the Longleaf Pine Flats of Louisiana

ARAVILLA MEEK TAYLOR

(WITH THREE TEXT FIGURES)

Saint Tammany Parish, Louisiana, lies directly north of Lake Pontchartrain and within the Coastal Plain region. In the northern part of the parish are the Longleaf Pine Hills. In these or in similar hills to the north, arise most of the streams which flow through the Longleaf Pine Flats that occupy the southern part of the parish and border the lake.

During the Quaternary period of the Pleistocene, a change in elevation of the land brought about the deposition of the Columbian, the youngest geological series of the Coastal Plain (Clendenin, 2). In the region of the pine flats there were laid down, and still persist, three clearly defined layers of the Columbian deposits: a brown loam mixed with a relatively small amount of humus at the surface; a heavy clay; and a gravel layer in contact with the Lafayette series below. In the pine flats the Columbian completely overlies the Lafayette beds, although the latter reach the surface in much of the pine hills region to the north where the Columbian has been largely eroded.

The extreme youth of the region of the pine flats is made evident by a study of the river systems. There are two general conditions under which meandering streams may develop: first, in the case of a mature stream which cuts a wandering course through the flood plain of its own making; and second, a stream which flows through a region of recent formation, geologically speaking, presenting a very gradual slope and great topographic uniformity. The latter condition is true here. The streams meander through an almost level country forming many loops and curves. In some places they are very deep, but there has been little widening because during flood periods the water overflows the low banks and spreads for great distances, meeting with little obstruction. This flood water, as well as any that falls on the land, runs off slowly compared with the precipitation in a hilly country. During the seasons of high water, a considerable amount of sand is distributed over the low land and is frequently built up into a natural levee, but only a very small quantity of fine silt material has accumulated up to the present time. In places, however, the streams have cut deep channels, leaving high vertical bluffs, and forming narrow, sandy plains or shelves between the bluff and the river.

Two streams in the vicinity of Covington, Louisianna, have been observed in connection with the present study, and in general illustrate these two conditions. The Tchefuncta River, flowing from the pine hills, meanders its way southward to its outlet into Lake Pontchartrain at Madisonville. The banks near Covington are low and, as a result, it is forming a natural levee and occasionally a sandy flood plain. The Bogue Falaya, also coming from the hills, flows through Covington and joins the Tchefuncta about two miles from the city. The volume is less and, while in some places it has low banks and is depositing sand over the adjoining country, in other localities near Covington it has formed high bluffs.

The water of the lake into which the Tchefuncta flows is slightly brackish from the influence of the tide from the Gulf of Mexico, so that it can be readily understood that this whole region of the pine flats is only a little above sea level. The altitude of Covington is but thirty-nine feet. This accounts to a great extent for the very slow erosive action of these streams.

The subtropical character of the region is indicated by the great variety of species of native trees and shrubs. The state of Louisiana can boast of more species of native trees and shrubs than any other state except Florida (Cocks, 3, 4). Even in the limited area examined along these rivers about one hundred species were identified. There is scarcely a dominance of any species either in the low lands or on the ridges. Farther back from the streams, however, one or the other of the two principal pines, the loblolly, *Pinus Taeda* L., or the longleaf, *Pinus palustris* Mill., may form pure stands, or the two may form mixed forests. The proximity to the tropics is seen also in the liana character of many plants.

To one accustomed only to our northern vegetation, the presence of sphagnum, *Sphagnum imbricatum* Hornsch., in almost every conceivable habitat such as ravines, anywhere in the wet pine woods, especially on the cut-over lands, along roadside banks, on the vertical face of clay river bluffs, and even in vacant lots and along the streets in town, strikes one with astonishment, but its wide distribution is a valuable key to the humidity of the climate and the marshy condition of the soil.

RAVINE AND RIDGE HABITATS

Along the Tchefuncta river are numerous shallow ravines extending from the bordering upland toward the river, and separated by low, thinly wooded, partly deforested ridges. These ravines are well covered by vegetation even at the head, indicating considerable age and slow erosion. In this region along the Tchefuncta there are no newly formed gullies, but within the city limits of Covington are several examples of early stages of gully formation which, although initiated by man, still have pursued such a natural course according to the known history, as to make it justifiable to consider these as examples of what must be very similar to the natural ravine formation.

Some eighteen years ago the particular part of the city under consideration was laid off in lots and, as is the custom in this level country previous to the establishment of underground drainage, ditches were cut across the lots. These drains when first made are about thirty inches wide and vary in depth from six to eight inches at the head, to ten to twelve inches at the outlet. Such a drain was cut across the block from Van Buren street to Mile Branch, a small and much twisted stream connecting two loops of the Bogue Falaya. The ditch has remained since that time undisturbed by man except as changes in the adjoining streets may have altered, to a slight extent, the amount of water entering at the head. At present, after the lapse of eighteen years, this ditch at the Van Buren street end is less than two feet deep and only three feet wide. Where it joins Mile Branch about three hundred feet away, its bottom is now on a level with the larger stream. At the deepest point it is six feet and a half below the surface and the gully is seven feet wide. The banks throughout are perpendicular, or slightly projecting at the top because of the tendency to undercut above the joining of the brown loam stratum and the much more compact clay layer below. The latter forms the floor in the deepest part, since the cutting here has not yet extended into the lower or gravel layer of the Columbian.

At the head of the ditch the sides are well covered with the liverwort, *Anthoceros punctatus* L., and the mosses, *Philonotis* *fontana* L., *Pogonatum brachyphyllum* (Michx.) Beauv., *Pogonatum brevicaula* (Brid.) Beauv., and *Catharinea angustata* Brid., mixed with grasses. On the bottom is a luxuriant growth of water pennywort, *Hydrocotyle umbellata* L. Toward the wider portion the mosses and liverwort continue for a time. *Riccia fluitans* (L.) A. Br. can also be found growing on the soil near the bottom and on sticks six inches above the normal level of the water. Slumped plants become common where cutting has increased. Small loblolly pines, oaks, and royal fern survive such a calamity with fair success, because of the high humidity and the abundant soil moisture. Where cutting is most rapid other vegetation is almost absent. However in the humid weather which frequently prevails in this latitude, a few weeks is often a sufficient time for a new surface, particularly on the clay, to become covered with the persistant protonema of the *Pogonatum* mosses—in one case two weeks showed a distinct green coat. There is no doubt that such mosses, even in this immature stage, are of great value in rendering the surface stationary, for even considerable flooding, unless accompanied by undermining, does not destroy the moss although the gametophores may not be present. Undercutting may be delayed sufficiently for gametophores and sporophytes to be produced, or for other species of moss to come in, but with heavy rains or the drying out of the clay layer after rains, slumping inevitably occurs and a new surface is exposed, so that in the deep part of the ditch, plants which formerly made up a part of the flora at the top, are virtually the only lateral vegetation. In the bottom in this portion, moisture is uniform enough for the support of *Myriophyllum scabratum* Michx. From all appearances it will be only a few years before the slope will become less acute, partly as a result of accumulation of the undermined soil at the foot of the bank. This has occurred near the outlet, and here the soil is being stabilized by the growth of plants similar in character to those at the head.

That a drainage ditch of such a type may, in this region, develop into a ravine can be seen along the Bogue Falaya River where a deep gorge-like ravine is in process of formation by the cutting back from the mouth of a drain which formerly extended from the river bluff, several hundred feet across the contiguous land. It is obvious that from the head of the present gorge the main ditch, which is now about one and a half feet deep and a yard wide, is not of recent origin. The margin is bordered by shrubs and young trees, and the sides are thickly covered by herbaceous vegetation and mosses. Instead of widening gradually and forming a long V as in the case of the Covington drain, this one has cut back from the bluff forming a somewhat U-shaped gorge of about fifty-four feet in width at the mouth, eighteen feet in depth and eighty-six feet in length, with clean-cut, nearly perpendicular lateral faces. With the exception of plants, mostly small trees such as sweet gum, red maple, loblolly pine, and oaks, which have been carried down from above, there is very little vegetation anywhere in this ravine. Moss protonema occurs here and there, but the paucity of even the pioneers testifies to the severe competition with the constant erosion. The bottom is nearly devoid of plant life and indicates distinct and recent water action.

At the head the wall makes a sheer drop from the upland. At about ten feet below the bottom of the drain, the wall is being undercut, forming a peculiar cave-like cavity three and one-half feet wide by one and one-half feet in the vertical direction, and at present extending backward into the clay for three feet. As this excavation enlarges, the soil will become loosened and the gorge will be extended farther back into the upland. (Observations made two years after these measurements were taken showed that the gorge had been extended in this manner fully two feet.) Erosion is going on with such rapidity throughout the entire gorge that both depth and width are nearly uniform from ditch to river bluff, and the floor is almost on a level with the comparatively low flood plain along this part of the river. The surface has not yet become sufficiently stabilized to permit seed germination to any extent.

We do not have a wide gap in condition between the broadest part of the ditch in Covington and the ravines previously mentioned along the Tchefuncta River, although it may represent many years in time. The latter, though evidently much older, are still in the temporary stream stage. The slopes are gradual, the soil is held in place by herbaceous vegetation and shrubs, and the ground flora is abundant. Sphagnum occurs frequently near the head and is often found well up on the slopes. Other mosses may be present but are not in large quantities. Among these

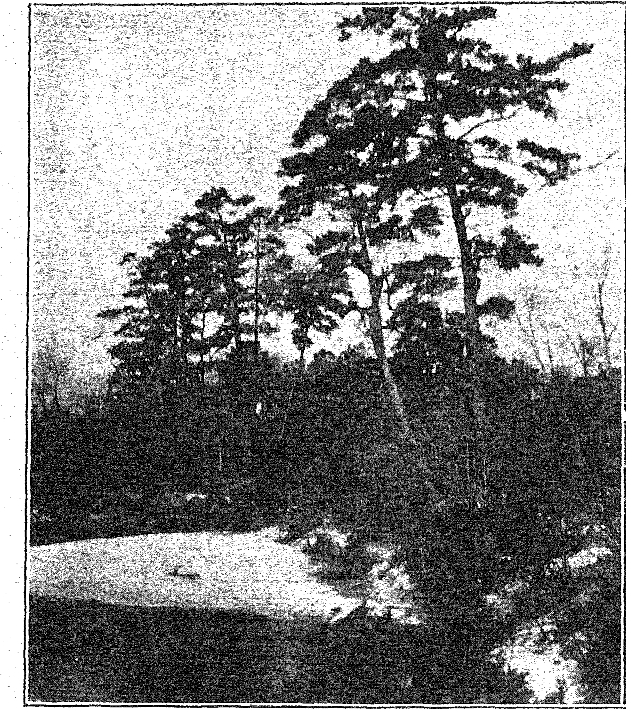

FIGURE 1.

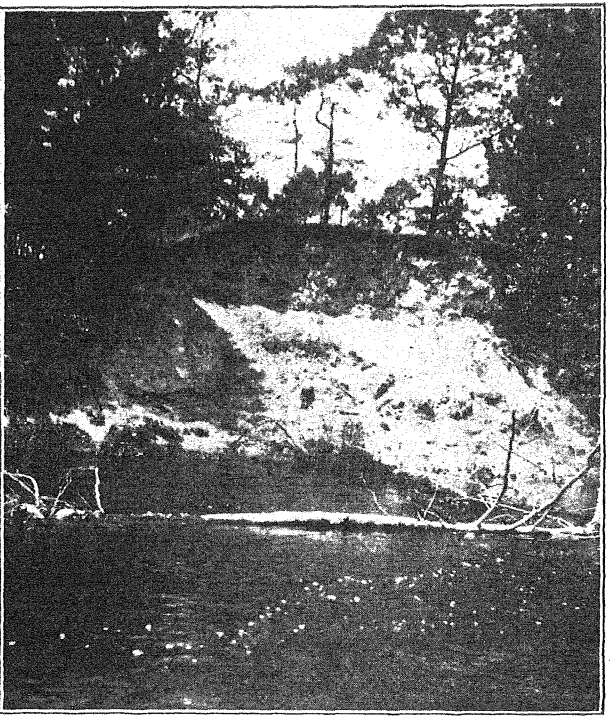

FIGURE 2.

are the two Pogonatums previously mentioned, *Entodon seductrix* Hedw., *Philonotis fontana* L., *Dicranella rufescens* (Dicks.) Schimper, *Fissidens obtusifolius* Wils., *Catharinea angustata* Brid., *Anomodon attenuatus* (Schreb.) Hueben., and *Thuidium delicatulum* L.

Liverworts of several species occur wherever there is considerable moisture. *Pallavicinia Lyellii* (Hook.) F. S. Gray, *Scapania nemorosa* (Schrad.) Dumort., and *Odontoschisma prostratum* (Swartz.) Trevis. are most abundant on moist soil, while *Porella pinnata* L. is the common form on sticks and tree bases. Ferns together with such hydrophytic plants as *Iris versicolor* L. and lizard's tail, *Saururus cernuus* L., cover the ground where the ravines widen. Among the ferns are *Athyrium asplenioides* (Michx.) Desv., *Dryopteris normalis* C. Chr., *Onoclea sensibilis* L., *Osmunda cinnamomea* L., *O. regalis* L., *Pteris aquilina* L. and *Woodwardia areolata* (L.) Moore. *Lycopodium alopecuroides* L. appears in isolated locations.

Shrubs of several species form a thick undergrowth except at the very head, while at the mouth of the ravines or in the low land into which they open are often dense thickets of *Carpinus caroliniana* Walt. Even near the head may be found large bay or gum trees. These do not in most cases show any indication of having slipped downward from the upland, but seem to have germinated on the ravine floor, and give a fair index to the time the ravines have been in the course of development and the very slow progress of the erosion. The fall to the low land is slight compared to that in the newly forming gorge along the Bogue Falaya. There is little active erosion at the present time, so that the ravines are changing in depth and width very slowly.

These ravines end, not at the river itself, but in a rather broad, low swale, probably of erosion origin also, now forming the confluence of many such small ravines, but having lost any distinctly ravine characters which it may formerly have possessed.

FIG. 1. A sand spit forming at a right-angled bend of the Bogue Falaya. The river can be seen between the spit and the farther bank. *Pinus Taeda* L. at the right and in the background.

FIG. 2. The Bogue Falaya cutting into the forested upland. The vertical face shows the three distinct layers of the Columbian deposit. In the stream is a stranded tree beginning to form a new sand bar, and diverting the current in the direction of the air bubbles seen in the water.

Such a region is sometimes called a 'Bay-gall' from the presence of bay trees (Alexander, 1). In this swale are many small streams some of which have reached the permanent stream stage, and have their outlets at the river, thus forming the drainage for the whole series of ravines. Large tupelo gums, with greatly expanded bases, are frequently seen in the middle of these permanent stream beds. From the presence of such trees in the center of the ravine floor in the younger parts of the ravines, it seems probable that these larger gums have started as seedlings during the temporary stream stage, and that they have been able to establish themselves and survive the subsequent very gradual changes of the soil by water action. The tupelo often grows in standing water of swamps, so that the stagnant condition of these streams during a part of the year does not seem to be detrimental to the later growth. Cypress occurs sparingly along the margins and increases as the streams approach the river. Along the bank of the river itself cypress is comparatively common. There seems to be some question relative to the cause of the small amount of young cypress growth even where there are old trees. Perhaps a little light may be thrown on the subject by a condition found by the writer when collecting seed for germination experiments. In this case only a small proportion of the very numerous seed balls was found to contain well developed seeds. However this may not be true for all seasons or for all localities.

During wet weather many small islands and peninsulas are formed by the joining of the flooded lowlands. The greater mesophytism of the encircled elevations is strikingly apparent in the ground flora, though noticeable also in the shrubby undergrowth. This may be partly a result of less disturbance by cattle, since the water forms a barrier during a considerable part of the growing season. It is on elevations of this sort that Christmas fern, *Polystichum acrostichoides* (Michx.) Schott, dogwood, *Cornus florida* L., and *Stewartia Malachodendron* L. are most common. In the lower part of the ravines and on these lowlands along the Tchefuncta are extensive thickets of *Carpinus caroliniana* Walt. Along the Bogue Falaya are similar thickets of alder, *Alnus rugosa* (DuRoi) Spreng. Both species occur on each river but are unequally distributed.

The narrow ridges now left between the ravines, as well as the more irregular elevations nearer the river, have at some remote period formed a part of the upland such as we find in the poorly drained pine lands beyond the head of the ravines on which water stands a considerable time after every rain, though it may be very dry during more or less of the summer. The ground flora on these wet pine flats must be such as can endure standing water at times with much desiccation at other periods. Here trumpets, *Sarracenia Sledgei* MacFar., pitcher plants, *Sarracenia psittacina* Michx., sundew, *Drosera brevifolia* Pursh, butterwort, *Pinguicula lutea* Walt., and *Lycopodium alopecuroides* L. are conspicuous because of their abundance. Loblolly pine is the dominant tree but it is mixed with some longleaf. On the ridges much better drainage has been established and even in wet weather the ground is no longer marshy. In many cases the ridge becomes narrowed almost to a point where two ravines join the low swale. Sundew is still abundant, but the trumpets, pitcher plants, butterworts, and *Lycopodium* have disappeared. Loblolly continues to reproduce along with a smaller quantity of longleaf.

The large pine timber over all of this section was removed by lumbering about eighteen years ago so that much of what is now present represents a secondary succession following cutting. Either by intention or accident a few mature pines were left within a short distance of the ridges so that there has been no lack of seeds. As can be seen anywhere in the wet pine flats region where fires and excessive grazing are prevented after deforestation, the pines will reëstablish themselves with little delay if seed trees are left. This has been the case on the semi-hydrophytic pine land beyond the head of the ravines, where the secondary tree succession in many places is exclusively loblolly and longleaf pines. On the ridges, however, while the loblolly is still abundant and the longleaf persists to some extent, xerophytic oaks are present also in great numbers. *Quercus marilandica* Muench., or Black Jack, is the dominant oak but other species such as *Q. alba latiloba* Sarg., *Q. Catesbaei* Michx., *Q. falcata* Michx., *Q. Prinus* Michx., and *Q. stellata* Wang. are coming in. *Carya alba* (L.) K. Koch accompanies the oaks. The indications are, therefore, that with the greater drainage and lessened surface moisture following the formation of the ravines, the original pines continued to grow without great difficulty. But when these were cut, the more xerophytic environment induced by the intense sunlight and consequent high evaporation following deforestation, combined with the decrease in soil moisture due to drainage, did not provide as favorable conditions for pine seed germination. The xerophytic oaks are better able to withstand such conditions, and their presence in abundance, accompanied by a few individuals of the less xerophytic types in the secondary succession, is a distinct forerunner of what the association following the pines will be when these flats are better drained.

Fire does not seem to have passed through the section at all recently. Cattle and hogs roam at will over the ridges and through the ravines, but while the herbaceous vegetation has been considerably disturbed by the animals, grazing has not been so excessive as to interfere greatly with either the tree seedlings or the shrubby undergrowth. Witch hazel, *Hamamelis macrophylla* Pursh, grows in profusion near the edge of the ravines and extends down the slopes. With it is chinquapin, *Castanea alnifolia floridana* Sarg., red maple, *Acer rubrum Drumondii* Sarg., and sweet gum, *Liquidambar styraciflua* L. Yaupon, *Ilex vomitoria* Ait., appears on the top but is rare. In the sections approaching greater mesophytism, sassafras, *Sassafras variifolium* (Salisb.) Kuntze., dogwood, *Cornus florida* L., azalea, *Rhododendron canescens* Sweet., and red mulberry, *Morus rubra* L., occur, but not in great abundance. Inkberry, *Ilex glabra* L., is a common shrub here, as in most of the cut-over pine lands not too often overrun by fires. A low-growing huckleberry, *Galussacia dumosa* (Andr.) Torr. & Gray, is another ubiquitous species of the ridges. Persimmon, *Diospyros virginiana* L., of small size occurs both here and in the land of poorer drainage.

The trees and shrubs of the slopes are not very distinctive. They are of small size in general and are a mixture of some of those from the bottom with some of the types found on the ridges. Because of the shallowness of the ravines, the change in moisture and light conditions is not great enough to produce a distinct slope association. Red maple, sweet gum, chinquapin, witch hazel, and water beech are characteristic trees and shrubs. Ferns mosses, and liverworts occupy the base of the slope, while more xerophytic herbaceous forms become conspicuous near the top.

RIVER BLUFF HABITAT

Although a smaller stream than the Tchefuncta, the Bogue Falaya has cut a deep channel in various places. At what is locally known as the 'Rapids' the stream makes a bend of approximately forty-five degrees and for some distance both up and down the river it flows between high bluffs. The current possesses considerable velocity in the continually curving channel and is cutting into the bluff on one side and depositing sand on the other. The sand layer on both shores is indicative of the constantly changing direction of the current, for there has been deposition in past times at many points where cutting is now going on. Refuse high up in the undergrowth is conspicuous evidence that at flood periods the river must be several feet above its normal level. From the stream to the bluff the distance varies from a foot or less to eighty feet or more. This narrow shelf or flood plain is well above the stream at low water, and is covered with a thick deposit of sand which, with the clay below, forms the substratum for a varied growth of vegetation. The bluff is nearly perpendicular and in many places the three strata of the Columbian formation, loam, clay, and gravel have been exposed. The erosion is increased materially by the numerous springs which emerge on the bluff in the clay layer. There is frequent slumping due to softening and undermining from the combined causes of seepage, river cutting, and surface drainage.

Next to the water the face of this shelf is steep and is often covered with liverworts and mosses. On the clay near the river and also along the bluff as well as on the sand are extensive patches of the liverwort, *Scapania nemorosa* (L.) Dumortier. *Odontoschisma prostratum* (Swartz) Trevis. is also comparatively, common, sometimes growing with the *Scapania*, but frequently occupying little sheltered hollows in the vertical clay face. *Pallavicinia Leyellii* (Hook.) F. S. Gray grows abundantly close to the water and also on the moist clay of the bluff. *Cephalozia catenulata* (Huben.) Spruce almost covers the bark of old logs, some of which are low enough to be washed by the river during overflow. On the smooth, tight bark of *Carpinus caroliniana* Walt., *Leucolejeunea unciloba* (Lindb.) Evans forms a rather scattered growth. *Anthoceros punctatus* L. can be found occasionally, but in small quantities. Among the mosses, *Catharinea angustata* Brid. is the most common. *Fissidens obtusifolius* Wils. occurs in small patches on the damp clay bank about springs. Several species of Hypnaceae appear with *Thuidium delicatulum* L., especially near the water. Overhanging the bluff in many places is a mat of *Leucobryum sediforme* Muell. held together by roots of shrubs still retaining a precarious attachment to the top of the bluff. This moss is common on the xerophytic bluff upland, and bears abundant sporophytes.

The marked similarity of the liverworts of the river bluff and of the ravines is highly significant, in that it, also, seems to be related to the humidity of the climate. One would not ordinarily expect to find as great a number of identical or closely related species on a river bluff exposed to strong winds and intense sunlight, and in protected shady ravines. Thirteen species in all were identified. Of the ten species of the ravines, six are also found on the river bluff. The genera *Cephalozia* and *Leucolejeunea* are represented in each habitat, but by a different species. *Fossombronia foveolata* Lindb. was found only on the river bluff, and *Calypogeia trichomanis* (L.) Corda. and *Riccardia latifrons* Lindb., only in the ravines.

In the streams are numerous small islands in various stages of becoming inhabited by plants. Many of these have originated in sand bars caused by driftwood, logs or uprooted trees washed down stream during floods. One such tree can be seen in the foreground in figure 2.

The shelf adjacent to the stream is occupied by trees and shrubs of many years growth. Black birch, *Betula nigra* L., frequently overleans the river. *Alnus rugosa* (DuRoi) K. Koch and *Viburnum scabrellum* (T. & G.) Chapman border the bank at the water's edge. *Liquidambar styraciflua* L., *Ilex opaca* Ait., *Quercus nigra tridentifera* Sarg., *Q. phellos* L., *Catalpa bignonioides* Walt., and *Acer rubrum Drummondii* Sarg. grow on the shelf proper and seem to have germinated *in situ.* Most of these species may be found also on the slope where they survive the hardship of slumping and aid in preventing further landslips. Among the shrubs of the shelf when well above the river, *Illicium floridanum* Ellis is perhaps most common.

Lianas are abundant and varied. *Tecoma radicans* (L.) Juss., *Vitis rotundifolia* Michx., *Psedera quinquefolia hirsuta* (Donn) Rehder., *Wisteria macrostachya* Nutt., *Gelsemium sempervirens* L., and several species of smilax climb far up into the trees. The ground vegetation is sparse, partly because of flooding resulting in covering, and partly because of disturbance by animals. These causes also unite in preventing an abundant undergrowth of tree seedlings, although some survive and become established.

The top of the bluff is so well drained as to be almost xerophytic. The trees are of the same species as those found in other well drained habitats in the vicinity. As in the case of the ridges, this upland has formerly been a part of the wet pine flats. With the lowering of the stream bed has come a corresponding lowering of the water table of the adjoining lands, and consequent decrease of surface moisture. Precipitated moisture, which comes often in a tropical downpour, flows over the bluff rapidly so that comparatively little penetrates the surface soil. *Leucobryum sediforme* Muell. may be very abundant for several feet back from the edge. Xerophytic herbaceous plants have nearly displaced the former semi-hydrophytic species of the wet pine flats, and xerophytic lichens occur under the trees. Oaks and a few hickories are taking the place of the pines. Beech seedlings are present under or about the mature beech trees. Beech in this vicinity occurs chiefly along the rivers, not on the low flood plain, but on what has been the former upland through which the rivers have cut their channels. It is, perhaps, too early in the development of the flora of the region to say that beech will follow the oak-hickory association, although this might be the logical hypothesis, judging from what does occur in the much older geological region of the north-eastern part of the United States.

BRICK AND BRICK WALL HABITAT

In this section of Louisiana there are few outcropping rocks, but an excellent substitute for a rock habitat was discovered in the bricks of old brick yards, long abandoned, and in old brick walls. It is not unusual to find a lusty growth of *Reboulia hemispherica* (L.) Raddi covering the brick foundations of houses or the brick walls of open drains in Covington. *Selaginella selaginoides* (L.) Link may also make its appearance on these walls, but is more often found on the soil of the banquette.

At Sulphur Springs on the Bogue Falaya River, and not far from Covington, are some old brick walls which were erected previous to the Civil War. At a short distance from the river are the outlets of several springs of sulphur and magnesium, the water of which is still valued for medicinal properties. Near to these springs was begun what was for those days a somewhat pretentious brick hotel. When only just well started, the war occured and building operations were abandoned. Probably owing to financial reverses incident to the war, the owners did not resume construction at its close. Some of the walls still standing are ten feet or more in height, and in an excellent state of preservation and apparently in nearly as substantial a condition as when first erected. Time and nature have covered the outer surface with plant life, but have made only slight inroads upon the mortar which holds the bricks together, for only here and there has a brick been displaced. Trees of several species and of large size surround and overshadow the walls. Thus the forest shade, the high humidity of the air during much of the year, the proximity of the Bogue Falaya, and the somewhat protected location among the low bluffs of the river unite in giving a favorable environment for the growth of rock species.

On the more exposed and therefore more xerophytic faces of the walls, crustose and foliose lichens with a few mosses form the only flora except for an occasional crevice species. But on the sheltered sides, exposed to the humid air without the desiccating influence of direct sunlight and wind, the surface is completely covered with the mosses *Cirrphyllum Boscii* (Schwaegr.) Grout, *Eurhynchium strigosum* (Hoffm.) B. & S., *Thuidium delicatulum* L., and a small amount of the liverwort *Reboulia hemisphaerica* (L.) Raddi. *Selaginella selaginoides* (L.) Link grows in sheltered corners, coming in as a later succession on the mosses. Wherever a brick has been dislodged, or the mortar has begun to disintegrate, and on the projecting ledges of brick left in building, typical crevice and ledge plants are prominent. At the base lianas have taken root in the ground and clamber upward, mingling their foliage with those rooted on the top and overhanging the edge. On the top are also many herbaceous plants, shrubs several feet high, and maple, pine, and oak seedlings. These are growing on a thick mat of mosses. The most common of the shrubs are *Myrica cerifera* L., *Evonymus americanus* L., and *Lonicera japonica* Thunb. The most conspicuous of the lianas are *Gelsemium sempervirens* L., *Psedera quinquefolia hirsuta* (Donn) Rehder, *Rhus Toxicodendron* L., and *Smilax rotundifolia* L. We have here a typical rock succession from the crustose lichens to the early tree stage.

Growing from the ground in the 'rooms' are mature trees of several species. Red mulberry, sweet gum, river birch, water beech, and loblolly pine scatter their ripened fruits among the slowly weathering bricks. The largest tree is a loblolly pine sixty-eight inches in circumference. (It has been determined by actual counting and measurement of the annual rings in work done by the Conservation Department of Louisiana, that in this climate the loblolly may make an average growth of nearly an inch in diameter in a year.) Climbing up the trunk of the pine—as can be seen in figure 3—are several lianas, the largest of which, a muscadine grape, is itself eight inches in circumference. The same mosses which are found on the wall are growing on the scattered bricks on the ground. *Reboulia* is here accompanied by *Anthoceros punctatus* L.

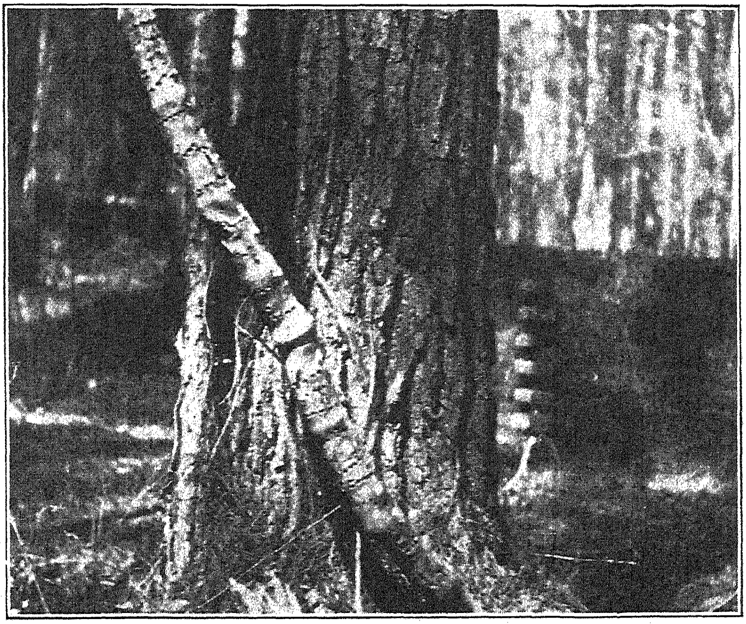

FIG. 3. *Pinus Taeda* L. growing in a 'room' of the old hotel. Muscadine grapes and other lianas find support on its trunk and branches.

Throughout the pine flats are many old abandoned brick yards. The broken bricks may be piled into heaps or distributed widely over the ground. Frequently during the passing years, the neighborhood about the old kilns has become converted into forest, again producing, through the combined agency of man and nature, a favorable situation for rock species. One of the most typical as well as the most interesting of such places visited is on the Tchefuncta at a point known as Fairview. Here in the midst of a forest is an old house, long uninhabited. The house is surrounded by immense live oak trees, *Quercus virginiana* L., with long streamers of Spanish moss, *Tillandsia usneoides* L., hanging from the branches. What is left of the roof is thickly thatched with *Polypodium polypodioides* (L.) Hitch. On the brick foundation is the most luxuriant growth of *Reboulia hemisphaerica* (L.) Raddi which was found in the entire region. Whole bricks, where loosened from the wall, are wrapped in it, and the cavities from which they have been dislodged are lined with it. It also forms a beautiful pattern on the old brick walks all about the house where it has to compete with the mosses.

Near the house are piles of bricks, the remains of a former brick yard. Here the liverwort occurs rarely, but mosses of several species are abundant, so that not a brick can be found without at least a tracery of moss, while some are covered with a mat thick enough to support the growth of small herbaceous forms, and tree seedlings. The cracks among the bricks provide a favorable location for *Asplenium platyneuron* (L.) Oakes, *Osmunda regalis* L., and *Dryopteris normalis* C. Chr., together with various seed plants. Once more we have a typical rock succession on bricks.

SUMMARY

1. The pine flats of Louisiana present several plant habitats typical of recently developed geological formations.

2. Of these the ravine and ridge habitats and the river bluff habitat have been considered in this paper.

3. Ravines are of gradual development as a rule, and changes in vegetation, resulting largely from changes in drainage, are correspondingly slow.

4. The ridges left between the ravines are narrow and well drained, and the vegetation shows a distinct secondary succession of mixed oak, hickory, and pine following the pine association of the wet flats.

5. The ravines are characterized by semi-hydrophytic and mesophytic species seldom met with on the wet uplands.

6. Where river bluffs occur, the faces are steep and, as a rule, the only plants are the pioneer species, though in places shrubs and trees have become established.

7. The top of the bluff is characterized by a mixture of semi-hydrophytic antecedent species and semi-xerophytic subsequent species.

8. As on the ridges, the pines are being followed by an oak-hickory association with here a greater possibility of a later succession of beech because of the presence of old trees.

9. Brick walls and abandoned brick yards present a typical rock succession from the pioneers to the young trees.

10. The semi-tropical character of the climate is obvious from the great variety of plant species, as well as from the similarity of these species to those of the humid tropics. The latter character is especially noticeable in the number of species of liverworts and in the lianas, when compared to the condition in similar habitats in the colder and dryer regions.

I wish to express my deep obligation to the following individuals who have so kindly rendered assistance in identification or verification of species: to the late Professor R. S. Cocks of Tulane University for the shrubs and trees; to Dr. George H. Conklin of Superior, Wisconsin for the liverworts; to Mr. George B. Kaiser of Philadelphia and Dr. LeRoy Andrews of Cornell University for the mosses; and to Mr. C. A. Weatherby of East Hartford, Connecticut for the ferns. I would also extend thanks to Dr. Henry C. Cowles of Chicago University for reading the manuscript, and to Miss S. J. Reeder and Miss Mina Kock, graduate students, for aid in collection and preparation of plant material. To Miss Reeder very special appreciation is due for her generous hospitality which made it possible to conduct the work.

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Literature cited

1. **Alexander, M. L.** The why and how of forestry in Louisiana. Bull. 7, Dept. of Conservation, State of Louisiana. 6 pp. 1922.
2. **Clendenin, W. W.** The Florida parishes of East Louisiana. Geology and Agriculture Report, Part III: 169–200. 1896.
3. **Cocks, R. S.** A list of the trees of Louisiana. Jour. Arnold Arboretum **2**: 204–216. 1922.
4. ———. A list of the shrubs of Louisiana. Jour. Arnold Arboretum **3**: 173–182. 1922.

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Aase, H. C., & Powers, L. R. Chromosome numbers in crop plants. Am. Jour. Bot. **13**:367–372. *pl. 29–30.* 18 Je 1926.

Abbot, E. V. Notes on the fungous flora of Iowa soils. Proc. Iowa Acad. Sci. **31**: 115–117. "1924" 1925.

Andrews, A. L. Bryophyta. 1926. (in A preliminary biological survey of the Lloyd-Cornell reservation. Bull. Lloyd Lib. 27: 53–57)

Andrews, E. F. Remarkable behavior of a veteran white oak. Torreya **26**: 54–55. *illust.* "Je" 2 Jl 1926.
Thrived under conditions which destroyed vegetation around it.

Arthur, J. C., & Kern, F. D. Conversations with European mycologists. Science II, **63**: 558–560. 4 Je 1926.

Ballard, C. W., Structural variations in *Erythroxylon* leaves. Jour. Am. Pharm. Assoc. **15**: 343–359; 433–453; 530–549. *illust.* My, Je, Jl, 1926.

Barker, H. D. Fruitlet black rot disease of pineapple. Phytopathology **16**: 359–363. *f. 1, 2.* 10 My 1926.

Barker, H. D. Plant diseases and pests in Haiti. Int. Rev. Sci. & Prac. Agr. n. s. **4**: 184–189. Ja-Mr 1926.

Bartram, E. B. *Mnium arizonicum* Amann. Bryologist **29**: 30–31. *f. 1–4.* "Mr" 13 My 1926.

Beals, A. T. Collecting in the mountains of North Carolina. Bryologist **29**: 19–22. "Mr" 13 My 1926.

Beals, A. T. Proposed plans for a preliminary Sullivant Moss Society check list of the mosses of North America. Bryologist **29**: 29. "Mr" 13 My 1926.

Benedict, R. C. New plant conservation laws. Am. Fern Jour. **16:** 59. 29 Je 1926.

Berry, E. W. Pleistocene plants from North Carolina. U. S. Geol. Surv. Prof. Paper 140C: 97–110. *pl. 45–57.* 1926.

Berry, E. W. The fossil seeds from the Titanotherium beds of Nebraska, their identity and significance. Am. Mus. Novitates 221: 1–8. *f. 1–7.* 21 Je 1926.

Blair, M. C. Sporogenesis in *Reboulia hemisphaerica.* Bot. Gaz. **81:** 377–400. *f. 1–3 + pl. 30–31.* 22 Je 1926.

Blakeslee, A. F. Bread molds and biochemical differences between sexes. Science II, **63:** 505. 14 My 1926.

Britton, N. L. Further botanical investigation in Porto Rico. Jour. N. Y. Bot. Gard. **27:** 97–102. My 1926.

Brooks, M. M. Effect of light of different wave lengths on penetration of 2,–6,– dibromo phenol indophenol into *Valonia.* Proc. Soc. Exp. Biol. & Med. **23:** 576–577. Ap 1926.

Brooks, M. M. The permeability of protoplasm to ions. Am. Jour. Physiol. **76:** 116–120. Mr 1926.

Brooks, M. M. Penetration into *Valonia* of oxidation-reduction indicators; estimation of the reduction-potential of the sap. Proc. Soc. Exp. Biol. & Med. **23:** 265–266. Ja 1926.

Brozek, A. Inheritance in the monkey-flower. A genetic study of crosses between *Mimulus quinquevulnerus, M. tigrinus* and *M. tigrinoides.* Jour. Hered. **17:** 113–129. *f. 1–9.* 25 My 1926.

Buchanan, R. E. The classification of the enzymes of microorganisms. Proc. Iowa Acad. Sci. **31:** 107–109. "1924" 1925.

Chamberlain, C. J. Hybrids in Cycads. Bot. Gaz. **81:** 401–418. *f. 1–13.* 22 Je 1926.

Christensen, J. J. The relation of soil temperature and soil moisture to the development of head smut of sorghum. Phytopathology **16:** 353–357. *f. 1.* 10 My 1926.

Chrysler, M. A. Abnormalities in *Botrychium* and certain other ferns. Bull. Torrey Club **53**: 279–288. *f. 1–5* + *pl. 9.* "My" 3 Je 1926.

Clark, J. A., & Hooker, J. R. Segregation and correlated inheritance in Marquis and Hard Federation crosses, with factors for yield and quality of spring wheat in Montana. U. S. Dept. Agr. Bull. 1403: 1–71. *f. 1–12.* My 1926.

Cockerell, T. D. A. *Lamium purpureum* in Colorado. Rhodora **28**: 112. 11 Je 1926.
In Bluebell Canyon, at Boulder.

Coulter, J. M. The history of organic evolution. Science II, **63**: 487–491. 14 My 1926.

Cover, L. A., Swabey, M. R., & Stout, A. B. A report on sterility in irises. Bull. Am. Iris Soc. 16: 3–38. *illust.* Jl 1925.

Davis, W. B. Physiological investigation of black heart of potato tuber. Bot. Gaz. **81**: 323–338. *f. 1–7.* 20 My 1926.

Denny, F. E. Effect of thiourea upon bud inhibition and apical dominance of potato. Bot. Gaz. **81**: 297–311. *f. 1–7.* 20 My 1926.

Denny, F. E. Second report on the use of chemicals for hastening the sprouting of dormant potato tubers. Am. Jour. Bot. **13**: 386–396. *pl. 31–34.* 18 Je 1926.

Detjen, L. R. Physiological dropping of fruits. I. Relation of pollination, fertilization and embryo abortion to abscission in fruits. Delaware Agr. Exp. Sta. Bull. 143: 1–47. *f. 1–7* + *pl. 1–5.* Mr 1926

Dodge, B. O., & Gaiser, L. O. The question of nuclear fusions in the blackberry rust, *Caeonia nitens*. Jour. Agr. Res. **32**: 1003–1024. *pl. 1–4.* 1 Je 1926.

East, E. M. The physiology of self-sterility in plants. Jour. Gen. Physiol. **8**: 403–416. 20 Je 1926.

Edgerton, C. W., & Tims, E. C. Notes on *Testicularia Cyperi*. Mycologia **18**: 169–171. *f. 1* + *pl. 20.* 1 Jl 1926.

Elders, A. T. Some pollination and cytological studies of sweet clover. Sci. Agr. **6**: 360–365. *f. 1–2.* Je 1926.

Ferguson, W. C. Contributions to the flora of Long Island, New York. Fourth paper. Bull. Torrey Club **53**: 303–308. "My" 3 Je 1926.

Fisher, G. L. Fern collecting in Mexico. Am. Fern Jour. **16**: 57–59. 29 Je 1926.

Fitch, H. W. Revised method for the quantitative determination of sulfur fungicides on foliage. Phytopathology **16**: 427–428. 15 Je 1926.

Fitzpatrick, H. M. Fungi. 1926. (in A preliminary biological survey of the Lloyd-Cornell reservation. Bull. Lloyd Lib. 27: 58–67)

Foster, A. S. The strip method for serial celloidin sections. Bot. Gaz. **81**: 339–341. *f. 1.* 20 My 1926.

Freer, R. S. Notes on the development of the gametophyte and embryo of *Asplenium angustifolium* Michx. Ohio Jour. Sci. **26**: 147–168. *f. 1–13* 4 Je 1926.

Frost, H. B. Polyembryony, heterozygosis and chimeras in *Citrus.* Hilgardia **1**: 365–402. *f. 1–7.* My 1926.

Fulmer, E. I. Some observations on the growth of yeast. Plant Physiol. **1**: 67–76. *f. 1–4.* Ja 1926.

Gail, F. W. Osmotic pressure of cell sap and its possible relation to winter killing and leaf fall. Bot. Gaz. **81**: 434–445. *f. 1–3.* 22 Je 1926.

Gaines, E. F., & Aase, H. C. A haploid wheat plant. Am. Jour. Bot. **13**: 373–385. *f. 1–10.* 18 Je 1926.

Gates, F. C., & Woollett, E. C. The effect of inundation above a beaver dam upon upland vegetation. Torreya **26**: 45–50. *pl. 3.* "Je" 2 Jl 1926.

Gilmore, K. A. Culture studies of *Psilocybe caprophila.* Bot. Gaz. **81**: 419–433. *pl. 32, 33.* 22 Je 1926.

Gleason, H. A. Ecological studies in Porto Rico. Jour. N. Y. Bot. Gard. **27**: 104–106. My 1926.

Gleason, H. A. Studies on the flora of northern South America—IX. Miscellaneous new species from British Guiana. Bull. Torrey Club **53**: 289–301. "My" 3 Je 1926.

2 genera, *Barnhartia* and *Tetrapodenia*, and species in *Combretum Cybianthus*, *Weigeltia*, *Lissocarpa*, *Prestonia* and *Odontonema* described as new.

Granovsky, A. A. Studies on leafhopper injury to apple leaves. Phytopathology **16**: 413–422. *pl. 24.* 15 Je 1926.

Gravatt, G. F. Maple wilt. U. S. Dept. Agr. Circ. 382: 1–14. *illust.* My 1926.

Gravatt, G. F., & Marshall, R. P. Chestnut blight in the southern Appalachians. U. S. Dept. Agr. Circ. 370: 1–11. *f. 1, 2 + pl. 1–10.* My 1926.

Graves, E. W. Some notes on the new hybrid Aspleniums. Am. Fern Jour. **16**: 48–50. *pl. 5.* 29 Je 1926.

Grundlach, M. General index to Experiment Station Record, volumes 26–40, 1912–1919. U. S. Dept. Agr. Office Exp. Stat. 1–640. 1926.

Haenseler, C. M. Plant diseases of New Jersey. (Tenth instalment) Apple diseases other than scab and blotch. (Eleventh instalment) Eggplant diseases. New Jersey Agr. **8**^{6}: 6–7. **8**^{10}: 6–7. *illust.* Je, O 1926.

Hansen, A. A. Rhododendron, glory of the Alleghenies. Nat. Mag. **7**: 349–350. *illust.* Je 1926.

Harper, R. A. Morphogenesis in *Dictyostelium*. Bull. Torrey Club **53**: 229–268. *pl. 6–8.* "My" 3 Je 1926.

Harter, L. L., Weimer, J. L., & Lauritzen, J. J. The comparative susceptibility of sweet potato varieties to black rot. Jour. Agr. Res. **32**: 1135–1142. 15 Je 1926.

Harter, L. L., & Whitney, W. A. Influence of soil temperature and soil moisture on the infection of sweet potatoes by the black-rot fungus. Jour. Agr. Res. **32**: 1153–1160. *f. 1–2.* 15 Je 1926.

Harvey, R. B., & Wright, R. C. Frost injury to tomatoes. U. S. Dept. Agr. Bull. 1099: 1–10. Au 1922

Hemenway, A. F. Late frost injury to some trees in central Kentucky. Am. Jour. Bot. **13**:364–366. *pl. 28.* 18 Je 1926.

Hendrickson, A. H. Certain water relations of the genus *Prunus*. Hilgardia **1**:479–524. *f. 1–18.* Je 1926.

Higgins, B. B. *Anthracnose* of pepper (*Capsicum annuum L.*) Phytopathology **16**: 333–345. *pl. 22–23.* 10 My 1926.

Hollick, A. Paleobotanical exploration in Porto Rico. Jour. N. Y. Bot. Gard. **27**: 102–104. My 1926.

Holzinger, J. M., & Bailey, J. W. *Webera erecta* (Lindb.) Limpr. in North America. Bryologist **29**: 23–24. *pl. 2.* "Mr" 13 My 1926.

Hopkins, E. F., & Wann, F. B. Relation of hydrogen-ion concentration to growth of *Chlorella* and to the availability of iron. Bot. Gaz. **81**:353–376. *f. 1–5.* 22 Je 1926.

House, H. D., Ransier, H. E., & Benedict, R. C. Saving the hart's tongue. Am. Fern Jour. **16**: 33–44. *pl. 3–4.* 29 Je 1926.

Howe, T. D. Development of embryo sac in *Grindelia squarrosa*. Bot. Gaz. **81**: 280–296. *f. 1 + pl. 28, 29.* 20 My 1926.

Hutchinson, J. The families of flowering plants. I. Dicotyledons. Arranged according to a new system based on their probable phylogeny. i–xiv, 1–328. *f. 1–264.* London, Macmillan, 1926.

Jackson, H. S. The rusts of South America based on the Holway collections—I. Mycologia **18**:13 9–162. *pl. 19.* 1 Jl 1926.

Several species and combinations, described as new.

Jansson, K. P. Rayless *Aster novi-belgii.* Rhodora **28**: 112. 11 Je 1926.

Janssonius, H. H. Mucilage cells and oil cells in the woods of the Lauraceae. Yale Univ. Sch. For. Trop. Woods **6**: 3–4. 1 Je 1926.

Johnson, D. S. A maritime station for *Schistostega osmundacea*. Bryologist **29**: 17–19. *f. 1–2.* "Mr" 13 My 1926.

Mt. Desert Island, Maine.

Johnston, E. S. A plant photometer. Plant Physiol. **1:** 89–90. Ja 1926.

Jones, P. M. Structure and cultural history of a Mycetozoan found in tobacco plants with mosaic-like symptoms. Bot. Gaz. **81:** 446–459. *f. 1–2 + pl. 34–37.* 22 Je 1926.

Keck, D. D. *Lonicera* and *Symphoricarpos* in southern California. Bull. So. Calif. Acad. Sci. **25:** 66–73. 31 My 1926.
Several varieties and combinations described as new.

Kimbrough, W. D. A study of respiration in potatoes with special reference to storage and transportation. Maryland Agr. Exp. Sta. Bull. 276: 51–72. *f. 1–6.* S 1925.

Kindle, E. M. A comparison of recent and late Champlain stages of McKay Lake as diatom habitats. Canad. Field Nat. **40:** 83–84. Ap 1926.

Koessler, K. K., & Durham, O. C. A system for an intensive pollen survey with a report of results in Chicago. Jour. Am. Med. Assoc. **86:** 1204–1209. 17 Ap 1926.

Lambert, E. B., Rodenhiser, H. A., & Flor, H. H. The effectiveness of various fungicides in controlling the covered smuts of small grains. Phytopathology **16:** 393–411. 15 Je 1926.

Leukel, R. W. Further experiments on the control of bunt of wheat and the smuts of barley and oats. Phytopathology **16:** 347–351. 10 My 1926.

Linder, D. H. A new species of *Araiospora* from British Guiana. Mycologia **18:** 172–178. *pl. 21.* 1 Jl 1926.
A. coronata

MacDougal, D. T. The hydrostatic system of trees. Carnegie Inst. Wash. Publ. 373: 1–125. *f. 1–21.* Ap 1926.

McKay, M. B. Potato wilt and its control. Oregon Agr. Exp. Sta. Bull. 221: 1–23. *f. 1–11.* Mr 1926.

Mackenzie, K. K. "*Acer saccharum* Marsh". Rhodora **28:** 111–112. 11 Je 1926.

McNair, J. B. Poison ivy. Field Colombian Mus. Nat. Hist. Leaflet 12: 1–12. *illust.* 1926.

Maheu, J. La flore cavernicole américaine (grottes de Mammoth cave et de city-cave, etat de Kentucky). Bull. Soc. Bot. France **73**: 39–57. *f. 1–3.* 3 My 1926.

Marsh, C. D., Roe, G. C., & Clawson, A. B. Rayless goldenrod (*Aplopappus heterophyllus*) as a poisonous plant. U. S. Dept. Agr. Bull. 1391: 1–24. *f. 1–10.* My 1926.

Mattoon, W. R., & Beal, J. M. Common forest trees of Mississippi. Mississippi Agr. Exp. Sta. Ext. Bull. 32: 1–80. *illust.* Ap 1925.

Mercier, A. Les orchidées au Bresil. La foret. Rev. Sci. (Paris) **64**: 244–247. *illust.* 24 Ap 1926.

Merrill, E. D. Additions to our knowledge of the Bornean flora, II. Philippine Jour. Sci. **30**: 79–87. My 1926.

Species in *Castanopsis*, *Coelodepas*, *Canarium*, *Pentace*, *Grewia*, *Kayea*, *Ardisia* and *Callicarpa*, described as new.

Merrill, E. D. An economical herbarium case. Torreya **26**: 50–54. *illust.* "Je" 2 Jl 1926.

Miles, L. E. New species of fungi from Mississippi. Mycologia **18**: 163–168. 1 Jl 1926.

In *Asterella*, *Dimerium*, *Mycosphaerella*, *Phyllachora*, *Scolecodothis*, *Phyllosticta*, *Septoria*, *Monochaetia*, *Cercospora*, and *Volutella*.

Morgan, T. H. William Bateson. Science II, **63**: 531–535. 28 My 1926.

Morris, H. E. Field wilt (*Fusarium*) of potatoes. Montana Agr. Exp. Sta. Bull. 184: 1–14. *illust.* Ja 1926.

Muenscher, W. C., & Wann, F. B. Myxomycetes, the slime moulds. 1926. (in A preliminary biological survey of the Lloyd-Cornell reservation. Bull. Lloyd Lib. 27: 68-70)

Muller, H. R. A. Physiologic forms of *Colletotrichum Lindemuthianum* (Sac. et Mag.) Bri. et Cav. in the Netherlands. Phytopathology **16**: 369. 10 My 1926.

Murneek, A. E. Effects of correlation between vegetative and reproductive functions in the tomato *Lycopersicon esculentum* Mill.) Plant Physiol. **1**: 3–56. *f. 1–11 + pl. 1–7.* Ja 1926.

Newton, R., Brown, W. R., & Martin, W. M. The extraction of plant tissue fluids and their utility in physiological studies. Plant Physiol. **1**: 57–65. *f. 1.* Ja 1926.

Ortega, J. G. El ebano de Mexico. Mex. For. **4**: 1–2; 21–23. Ja–F 1926.

Overholts, L. O. Mycological notes for 1925. Mycologia **18**: 179–184. *f. 1 + pl. 22.* 1 Jl 1926.

Pack, D. A. The effect of moisture on the loss of sugar from sugar beets in storage. Jour. Agr. Res. **32**: 1143–1152. 15 Je 1926.

Parish, S. B. *Cereus Munzii* sp. nov. Bull. So. Calif. Acad. Sci. **25**: 48. 31 My 1926.

Parks, H. E. Tahitian fungi collected by W. A. Setchell and H. E. Parks. Univ. Calif. Publ. Bot. **12**: 49–59. 14 My 1926.

Perry, F. Mosses in British Columbia—their importance under local conditions. Canad. Field Nat. **40**: 81–83. Ap 1926.

Piness, G., Miller, H., & McMinn, H. E. Botanical survey of southern California in relation to the study of allergic diseases. Bull. So. Calif. Acad. Sci. **25**: 37–47. *f. 1–5.* 31 My 1926.

Piper, C. V. Studies in American Phaseolineae. Contr. U. S. Natl. Herb. **22**: i–viii, 663–701. *pl. 64.* 12 Je 1926.

Two genera, *Condylostylis* and *Alepidocalyx* and many species described as new.

Plagge, H. H., Maney, T. J., & Gerhardt, F. Certain physical and chemical changes of Grimes apples during ripening and storage period. Iowa Agr. Exp. Sta. Res. Bull. **91**: 43–72. *f. 1–12.* Ap 1926.

Plakidas, A. G. Strawberry "yellows," a degeneration disease of the strawberry. Phytopathology **16**: 423-426. *f. 1.* 15 Je 1926.

Rands, R. D. Root disease of sugar cane in Louisiana. U. S. Dept. Agr. Circ. 366: 1–19. *illust.* 1926.

Record, S. J. Central American Pteridophyta collected by Samuel J. Record, January–March, 1926. Yale Univ. Sch. For. Trop. Woods 6: 18. 1 Je 1926.
Identifications by W. R. Maxon.

Reed, F. D. Flora of an Illinois coal ball. Bot. Gaz. **81**: 460–469. *f. 1 + pl. 38.* 22 Je 1926.

Reed, H. S., & Halma, F. F. Further observations on the relations between growth and sap concentration in citrus trees. Jour. Agr. Res. **32**: 1177–1194. *f. 1–10.* 15 Je 1926.

Reinking, O. A. Banana freckle and leaf spot. Mycologia **18**: 185–186. 1 Jl 1926.

Reinking, O. A. *Fusaria* inoculation experiments. Relationship of various species of *Fusaria* to wilt and Colorado disease of banana. Phytopathology **16**: 371–392. *f. 1–8.* 15 Je 1926.

Ricker, P. L. Native trees, shrubs, and flowers for golf courses II. Bull. Green Sect. U. S. Golf Assoc. **6**: 60–63. *illust.* 16 Mr 1926.

Robinson, M. F. Tree leaves—their story. Nat. Mag. **7**: 367–371. *illust.* Je 1926.

Ross, H. "Über die Kletterhaken einer brasilianischen Apocynacee. Flora **118–119**: 453–459. *pl. 6.* 1925.
Dipladenia Leutzelburgii.

Rusby, H. H. A rain-tree in Bolivia. Yale Univ. Sch. For. Trop. Woods 6: 12. 1 Je 1926.
Vouacapoua pluvialis.

Sanford, S. N. F. *Erechtites megalocarpa* in Rhode Island. Rhodora **28**: 111. 11 Je 1926.
At Sachuest Neck.

Savicz, V. P. Notes on *Cetraria chrysantha* Tuck. and *C. lacunosa* Ach. in Russia. Bryologist **29**: 26–28. "Mr" 13 My 1926.
1 form described as new.

Schaffner, J. H. Additions to the catalog of Ohio vascular plants for 1925. Ohio Jour. Sci. **26**: 169–182. 4 Je 1926.

Schaffner, J. H. *Equisetum variegatum Nelsoni*, a good species. Am. Fern Jour. **16**: 45–48. 29 Je 1926.

Schulz, E. R., & Thompson, N. F. Chemical composition of etiolated and green *Berberis* sprouts and their respective roots. Bot. Gaz. **81**: 312-322. *f. 1–2.* 20 My 1926.

Sears, P. B. The natural vegetation of Ohio. II. The prairies. III. Plant succession. Ohio Jour. Sci. **26**: 128–146; 213–231. *f. 1–7.* 4 Je; 23 S 1926.

Seaver, F. J. Ellsworth Bethel. Mycologia **18**: 187–188. *port.* 1 Jl 1926.
Born 20 Je 1863. Died 8 S 1925.

Seaver, F. J. Mycological work in the Bermuda Islands. Mycologia **18**: 137–138. *pl. 18.* 1 Jl 1926.

Setchell, W. A. Tahitian algae collected by W. A. Setchell, C. B. Setchell, and H. E. Parks. Univ. Calif. Publ. Bot. **12**: 61–142. *pl. 7–22.* 14 My 1926.

Setchell, W. A. Tahitian spermatophytes collected by W. A. Setchell, C. B. Setchell and H. E. Parks. Univ. Calif. Publ. Bot. **12**: 143–240. *pl. 23–36.* 14 My 1926.
Cyrtandra Parksii described as new.

Sherff, E. E. Revision of the genus *Isostigma* Less. Bot. Gaz. **81**: 241–257. *pl. 23–24.* 20 My 1926.

Small, J. K. Cycads. Jour. N. Y. Bot. Gard. **27**: 121–129. *f. 1–2.* Je 1926.

Small, J. K. A new butterfly-pea from Florida. Torreya **26**: 56–57. "Je" 2 Jl 1926.
Clitoria fragrans.

Small, J. K. A new pawpaw from Florida. Torreya **26**: 56. "Je" 2 Jl 1926.
Asimina tetramera.

Smith, E. F. Changes of structure due to a modified environment. A study of labile protoplasm in *Helianthus annuus* L. Science II, **63**: 505. 14 My 1926.

Smith, E. F. Fasciation of Dahlia. Jour. Hered. **17**: 112. *frontispiece.* 25 My 1926.

Smith, E. F. Recent cancer research. Am. Nat. **60**: 240–256. My-Je 1926.

Spegazzini, C. Observaciones y adiciones a la micologia Argentina. Bol. Acad. Nac. Ci. Argentina **28**: 267–406. 1926.
Many species described as new.

Stout, A. B. The capsules, seed, and seedlings of the tiger lily, *Lilium tigrinum*. Bull. Torrey Club **53**: 269–278. *f. 1–4.* "My" 3 Je 1926.

Stout, A. B. Further notes on the flowers and seeds of sweet potatoes. Jour. N. Y. Bot. Gard. **27**: 129–135. *f. 1.* Je 1926.

Thung, T. H. *Peronospora parasitica* (Pers.) DeBy. attacking cabbage heads. Phytopathology **16**: 365–366. *f. 1.* 10 My 1926.

Tiffany, L. H. The filamentous algae of northwestern Iowa with special reference to the Oedogoniaceae. Trans. Am. Micros. Soc. **45**: 69–132. *pl. 1–16.* Ap 1926.

Tirona, M. Nature and availability of the plant-food constituents of Philippine guano. Philippine Jour. Sci. **30**: 69–78. My 1926.

Torrend, C. Les polyporacées stipitées du Bresil (cont.) Broteria Ser. Bot. **22**: 5–19. *pl. 1.* Mr 1926.

Trelease, W. Some puzzling pepper leaves. Proc. Am. Phil. Soc. **65**: 64–67. *f. 1–4.* 22 Ap 1926.

Uppal, B. N. Toxicity of organic compounds to the spores of *Phytophthora colocasiae* Rac. Jour. Agr. Res. **32**: 1069-1097. 1 Je 1926.

Vainio, E. A. Lichenes Mexicani a F. M. Liebmann annis 1841–1843 collecti, in Museo Hauniensi asservati. Dansk Bot. Arkiv 4^{11}: 1–25. 10 F 1926.
Many species described as new.

Valleau, W. D., & Johnson, E. M. A method of growing corn seedlings (*Zea mays*) free from seed-borne organisms. Jour. Agr. Res. **32**: 1195–1198. *f. 1–3.* 15 Je 1926.

VanderLaan, W. C., & Legg, W. D. Florida plants, a series of lists for reference. I. Trees. Land. Arch. **16:** 169–172. Ap 1926.

Vanterpool, T. C. Streak or winter blight of tomato in Quebec. Phytopathology **16:** 311–331. *f. 1–3.* 10 My 1926.

Watt. G. *Gossypium.* Kew Bull. Misc. Inf. **1926:** 193–210. 1926.

Weatherby, C. A. Forked and crested forms of ferns. Am. Fern Jour. **16:** 60. 29 Je 1926.

Weir, J. R. A pathological survey of the Para rubber tree (*Hevea brasiliensis*) in the Amazon valley. U. S. Dept. Agr. Bull. 1380: 1–129. *pl. 1–33.* My 1926.

Weldon, G. P. Instability in peach varieties. Jour. Hered. **17:** 133-135. *f. 10–11.* 25 My 1926.

Werner, H. O. The spindle-tuber disease as a factor in seed potato production. Nebraska Agr. Exp. Sta. Res. Bull. 32: 1–128. *f. 1–34.* My 1926.

Wheeler, L. A. A few more fern finds. Am. Fern Jour. **16:** 50–54. 29 Je 1926.
In Vermont.

White, O. E. Peas and people. Brooklyn Bot. Gard. Rec. **15:** 141–148. Jl 1926

White, R. P. *Rhizoctonia* crown rot of carrots. Phytopathology **16:** 367–368. *f. 1.* 10 My 1926.

White, R. P. Tomato wilt investigations. Kansas Agr. Exp. Sta. Tech. Bull. 20: 1–32. F 1926.

Wiegand, K. M., & Eames, A. J. The flora of the Cayuga Lake Basin, New York. Vascular plants. Cornell Agr. Exp. Sta. Memoir 92: 1–491. *2 maps.* My 1926.

Wiegand, K. M., Eames, A. J., & others. Vascular plants (Pteridophyta and spermatophyta). 1926. (in A preliminary biological survey of the Lloyd-Cornell Reservation. Bull. Lloyd Lib. 27: 25–52).

Winkler, A. J. Some responses of *Vitis vinifera* to pruning. Hilgardia **1:** 525–543. *f. 1–6.* Je 1926.

Wolf, J. A. Tuckahoe on maize. Jour. Elisha Mitchell Sci. Soc. **41:** 288–290. *pl. 66, 67.* Ap 1926.

Wolf, F. A., & Dodge, B. O. Anthracnose of dewberries and its control. No. Carolina Agr. Exp. Sta. Bull. 248: 1–16. *f. 1–5.* F 1926.

Woronichin, N. N. *Exobasidium caucasicum* Woronich. in Transcaaucasia and Kamchatka. Phytopathology **16:** 293–297. 10 Ap 1926.

Yampolsky, C. Origin of sex in the phanerogamic flora. Genetica **7:** 521–532. 1925.

Young, P. A. Penetration phenomena and facultative parasitism in *Alternaria, Diploida* and other fungi. Bot. Gaz. **81:** 258–279. *pl. 25–27.* 20 My 1926.

Zeller, S. M. European canker of pomaceous fruit trees. Oregon Agr. Exp. Sta. Bull. 222: 1–52. *f. 1–24.* Mr 1926.

Variations in the mature antheridium of the Characeae: A descriptive study in morphogenesis

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(WITH THIRTEEN TEXT FIGURES AND PLATES 10–14)

In method of development and symmetry the Characeae are perhaps the most diagrammatic of any organism, plant or animal. It is not merely that their radial and metameric organization results in the well proportioned chandelier-like form, which was noticed by the earliest students of this group, but their cellular make-up is so simple as to at once suggest the possibility of mathematical analysis. Since the time of Schleiden (1842) and Nägeli (1845, 1845, 1860), when it was hoped that the growth and development of plants could be represented by mathematical formulae representing the number and order of succession of the divisions of an apical cell, the Characeae have served as classical examples of diagrammatic regularity of growth and development. According to Giesenhagen (1896, 1897, 1898), Ernst (1904), Kuczewski (1906), Witt (1906), Müller (1907), Nonweiler (1907) and Sluiter (1910) the number and order of succession of the divisions of the apical cell of the Characeae is so regular and unvarying that the development of the whole apical end of the plant, leaves, stipule crown, cortications and side branches may be represented by mathematical formulae.

By reason of its position on the plant and the fact that in *Nitella* the terminal cell of the leaf becomes the antheridium, while in *Chara* it is developed from the cell which otherwise gives rise to the leaflet, the antheridium of the Characeae has been regarded as morphologically equivalent to the end cell of a leaf or leaflet. Celakovsky (1878), Sachs (1882), Ernst (1901) and Goebel (1902, 1918) consider the antheridium as a metamorphosed terminal segment of a leaf. Moreover, since capitula and antheridial filaments are often formed within oogonia in *N. syncarpa*, and vegetative branches may be formed from the basal cell instead of antheridia and oogonia, antheridia in place of oogonia or vice versa, and vegetative branches within oogonia

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in *C. foetida*, Ernst and Goebel regard the antheridium and oogonium as homologous structures which may be readily modified by environment. Goebel further suggests that the first division of the antheridium may correspond to the first divisions of a vegetative organ, with the exception that the cells which grow out to form the leaflet remain together. In connection with a study of nuclear and cell division in the Characeae I have had frequent occasion to observe a number of striking variations in the structure of the antheridium from the more usual and regular condition described by Meyen (1827, 1839), Varley (1849), Braun (1853) and Sachs (1882). The explanations of these deviations in the structure of the antheridium is not obvious, but a broad descriptive and comparative study of the facts of variation may lead to a clearer understanding of the morphogenetic problems presented by this group of plants.

According to Meyen (1827), Braun (1853) and Sachs (1882) the mature antheridium of the Characeae usually consists of eight outer shield cells, eight manubria, eight primary capitula, forty-eight secondary capitula, and four antheridial filaments borne on each of the latter. The variations which I have observed may be classified for the sake of convenience into eight groups, which will be considered in the following order: (1) Development of tertiary and quaternary capitula; (2) Variations in the size and number of primary capitula and manubria; (3) Branching of antheridial filaments; (4) Irregular partitioning of antheridial filaments; (5) Variations in the size of cells and nuclei of antheridial filaments; (6) Variations in the number of antheridial filaments borne on the capitula; (7) Variations in the number of cells in the antheridial filaments, and (8) Budding of manubria and capitula.

This study was made on freshly mounted and dissected antheridia of *N. fexilis* Ag., *N. gracilis* (Smith) Ag., *N. batrachosperma* (Reichenb.) A. Braun, *C. coronata* (Ziz.) f. maxima, *C. coronata* (Ziz.) f. Schweinitzii, *C. fragilis* (Desv.), *C. baltica* (Fries) Wahlstedt, *C. contraria* A. Braun, *C. zeylanica* (Will.). *C. delicatula* (Agardh), *C. vulgaris* L. and *Lamprothamnus alopercoides* (Del.) A. Braun, stained intra vitam with aceto-carmine, made up according to the formula used by Belling (1921). In each species, with the exception of *L. alopercoides*, antheridia from plants growing in the laboratory were compared with antheridia from plants in the field to determine whether or not the variations might be the result of differences in environment. Single antheridia were mounted and dissected each time in order to note the number and different types of variations in each antheridium examined.

The method of preparing the aceto-carmine preparations was as follows: After removing the antheridia from the plant and mounting in a drop of aceto-carmine, the shield cells were peeled off with fine steel needles, exposing the manubria, capitula and antheridial filaments. The antheridial filaments and capitula were then carefully separated under the low power of the microscope with as little injury as possible. As soon as the cover glass was added the mount was ready for study. This method has a decided advantage over the study of the same problem from fixed and sectioned material, since the antheridial filaments are so closely coiled and twisted about in the mature antheridium that it is almost impossible to follow with certainty the course of several or even a single filament in serial sections. By the aceto-carmine method described it is possible to separate single entire filaments and capitula, and the pressure of the cover glass when added is sufficient to bring them into the same focal plane where they may be photographed with readiness. Moreover, as pointed out in a previous paper (1926) the aceto-carmine does not essentially modify the cell organs except to cause a slight swelling, and so brings out their elements in greater detail and sharpness. The photographs of these aceto-carmine preparations shown in plates 10 to 14 leave much to be desired, but their clearness is, none the less sufficient to bring out the morphological and cytological details of these variations.

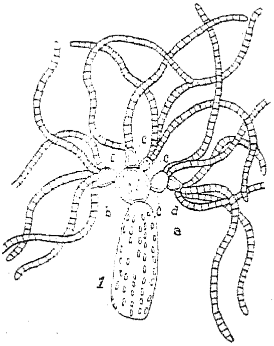
TERTIARY AND QUARTERNARY CAPITULA

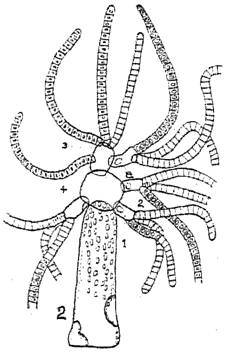
Each manubrium, according to Meyen, Braun, and Sachs, usually bears one primary capitulum on which are generally developed six secondary capitula. These secondary capitula in turn bear more or less regularly four antheridial filaments. I have frequently observed that in addition to antheridial filaments the secondary capitula may bear other capitula-like cells, which in turn bear antheridial filaments also. These cells are essentially like the secondary capitula in structure and function, and since they are borne on the latter they may very well be classed, it seems to me, as *tertiary capitula*. Figure 1 shows a secondary capitulum, bearing three antheridial filaments, *1*, *2*, and *3*, and one tertiary capitulum *b*, which in turn bears two filaments, *4* and *5*. A similar case is shown in figure 4 in which the secondary capitulum, bears three and the tertiary capitulum two antheridial filaments. In figures 5 and 6 the secondary and tertiary capitula, *a* and *b* respectively, each bear four filaments. It is to be noted that in all these figures the tertiary capitula are considerably smaller than the secondary capitula and do not exceed much in diameter the antheridial filaments which they bear.

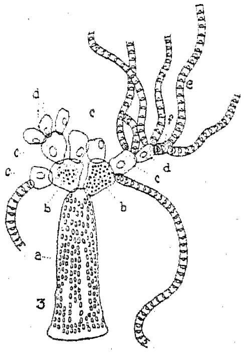
Figure 2 is exceptionally good in that it shows the capitula and antheridial filaments in relation to the manubrium. In this figure the manubrium is shown with one primary capitulum, *a*, a secondary capitulum, *b*, and two tertiary capitula, *c* and $c.^1$ In dissecting the antheridium in this case the secondary capitulum was torn partly loose from the primary capitulum. The primary capitulum bears one antheridial filament, number 9, and the secondary capitulum three filaments, numbers 6, 7, and 8. The tertiary capitulum c^1 developed one filament, which after a short period of growth formed three branches; while the second tertiary capitulum *c* bears five filaments, numbered consecutively. Thus, the secondary capitulum with the aid of two tertiary capitula bears eleven antheridial filaments. Figure 3 shows a large secondary capitulum with three tertiary capitula, in addition to two antheridial filaments, one of which has been torn off near the base. In *N. flexilis* I have observed as many as four tertiary capitula on one secondary capitulum.

Like the secondary capitula, the tertiary capitula may also bear other capitula on which antheridial filaments are borne. I have called this fourth series of cells *quaternary capitula*. Figure 74, shows a secondary capitulum, *1*, bearing two tertiary capitula, one of which is obscured by the antheridial filaments. The other secondary capitulum, *2*, bears three filaments and one quaternary capitulum, *3*, which in turn bears two antheridial filaments. The quaternary capitulum is partly obscured by one of the filaments from the tertiary capitulum, but the photograph is sufficiently clear to show that it is borne on the secondary capitulum. The diameter of the quaternary capitulum is only slightly greater than that of the antheridial filaments which it bears.

Wallroth (1815), Meyen (1827 and 1839). Fritsche (1827), Kützing (1843), Varley (1849), Sachs (1882), and Small (1921) figure cells borne on the secondary capitula that correspond in every respect to the cells which I have called tertiary capitula. None of these investigators with the exception of Small, however, recognize these cells specifically as such, and Sachs whose figures are copied extensively in text-books, states definitely, p. 301, that the whip-like antheridial filaments are borne on secondary capitula. In text-figures 1 to 5 I have reproduced Fritsche's (1837, fig. 8, pl. 2), Meyen's (1839, fig. 17, pl. 12), Kützing's (1843, fig. 12, pl. 38), Varley's (1849, fig. 31, pl. 21), and Sachs' (1882, fig. 198B) drawings showing the arrangement and manner in which the capitula and antheridial filaments are borne.







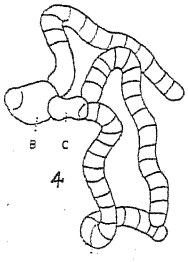
Text-figure 1. Fritzsche's figure 8, plate 2. a, Manubrium; b, primary capitula; c, secondary capitula; d, tertiary capitulum.

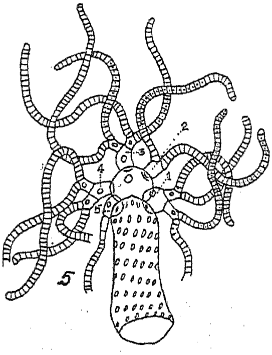
Text-figure 2. Meyen's figure 17, plate 12. *1, 2, 3* and *4*, secondary capitula; a, tertiary capitulum.

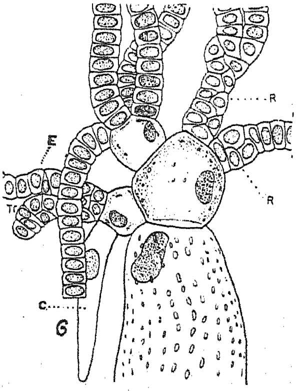
Text-figure 3. Kützing's figure 12, plate 38. a, manubrium; b, primary capitula; c, secondary capitula; d, tertiary capitula; f, branched filament.

Fritsche's figure 8, plate 2, reproduced in text-figure 1, shows a primary capitulum, *b*, with four secondary capitula, *c*, one of which bears a tertiary capitulum. Text-figure 2 shows Meyen's (1839) figure 17, plate 12, in which the large primary capitulum bears four secondary capitula, numbered consecutively, one of which, *3*, has developed a tertiary capitulum. In text-figure 3, is shown Kützing's figure 12, plate 30, in which he shows a manubrium, *a*, with two primary capitula, *b*, on which are borne five secondary capitula. One of the secondary capitula bears three, while another bears one tertiary capitulum. Text-figure 4 shows figure 31, plate 21, by Varley in which the secondary capitulum, *b*, bears a tertiary capitulum, *c*, and one antheridial filament. Sachs' figure 198B is shown in text-figure 5. The secondary capitula numbered 1, 3, and 4 each bear two tertiary capitula. Small (1921), figure 934, shows quaternary as well as tertiary capitula in *C. fragilis*.

In addition to being borne on quaternary, tertiary, and secondary capitula the antheridial filaments may sometimes arise directly from the primary capitulum. I have observed this in *Nitella*, *Chara*, and *Lamprothamnus*. Figure 7 shows a manubrium of *C. delicatula* with two primary capitula, one of which bears an antheridial filament. A similar case from *N. flexilis* is shown in figure 9 in which the primary capitulum, *a*, bears two filaments. Figure 13 shows a capitulum *b* with one filament, which I have dissected loose from the manubrium, *a*, on which it was borne. As is shown in figure 21, the primary capitulum in *L. alopercoides* may also give rise to antheridial filaments directly.





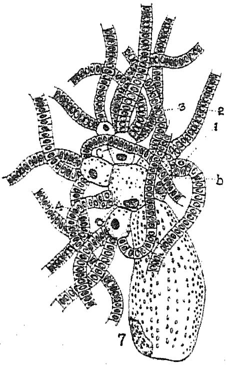


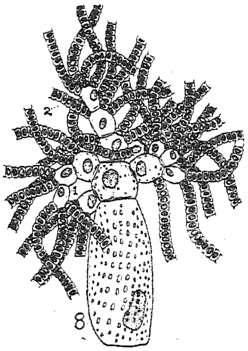
Text-figure 4. Varley's figure 31, plate 21. b, secondary capitulum; c, tertiary capitulum.

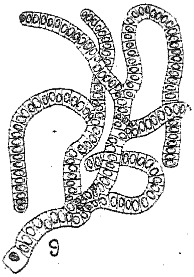
Text-figure 5. Sachs' figure 198B. *1*, *2*, *3*, *4*, and *5*, secondary capitula.

Text-figure 6. Two antheridial filaments, *R* and *R*, of *C. fragilis* directly attached to the primary capitulum whose bases are irregularly partitioned. C, a filament consisting of a single cell; T, a short irregularly divided filament.

In regard to the question as to the number of cell generations between manubrium and antheridial filament differences in observation exist in the literature today. Wallroth (1815) in figure 4, pl. 5, shows antheridial filaments borne on cells whose relative positions suggest that they may be secondary and tertiary capitula. Kaulfuss (1825) describes the filaments as being frequently borne on the manubria, and in figures 4C and 5 D Agardh (1826) figures the antheridial filaments arising directly from the manubrium. Two years later Bischoff (1828, fig. 31, pl. 2) shows a manubrium with a primary capitulum bearing two secondary capitula, on each of which are borne four antheridial filaments. Again in the same year, Schultz (1828) shows the filaments (figure 3, plate 3) arising directly from the manubrium. Thuret (1840, fig. 6, pl. 5, and 1851 fig. 5, plate 8) much later figures and describes the filaments arising from the primary capitula without the development of the secondary capitula. However, he describes and figures a cellular mass in the center of the antheridium which possibly may have been a group of secondary capitula.





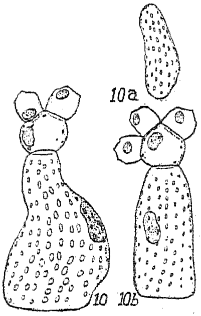


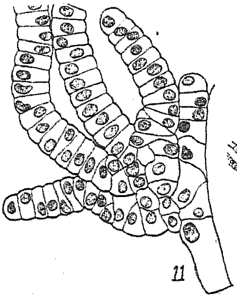
Text-figure 7. A manubrium of *C. fragilis* with two primary capitula, a and b, which bear antheridial filaments, *1*, *2*, *3*, and *4*, directly. The secondary capitulum *c* bears four antheridial filaments and one tertiary capitulum.

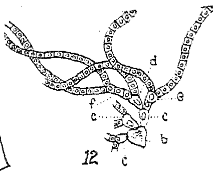
Text-figure 8. A manubrium of *N. flexilis* with one primary capitulum, four secondary capitula, five tertiary capitula and two quaternary capitula, *1* and *2*.

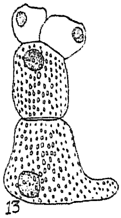
Text-figure 9. A branched antheridial filament of *N. flexilis*.

In most text-books of botany there are likewise conflicting reports on the manner in which the antheridial filaments are borne. Schenk (1882), Warming (1890), Strasburger (1895, 2 ed. and 1908, 3rd Eng. ed.), Vines (1898) and Van Tieghem (5th ed.) as late as 1918 figure and describe the antheridial filaments arising from the primary capitula, without the development of secondary or tertiary capitula. Sachs (1882), Campbell (1907), and Small (1921) figure the antheridial filaments arising generally from the secondary capitula, and in the fifth English edition of Strasburger's text-book the filaments are likewise described as being borne on the secondary capitula. Campbell (figure 91A) shows that the filaments may be borne on the primary capitulum as well as on secondary capitula, and in figure 934 Small describes the development of filaments on tertiary and quaternary capitula. Conflicting as these reports may seem, most of them are, nevertheless, correct. As is shown in plates 1 to 4 of my preparations, antheridial filaments may arise from primary, secondary, tertiary and quaternary capitula, but the majority of filaments in an antheridium are borne on secondary capitula. In none of the species examined have I observed filaments borne on manubria.









Text-figure 10–10b. Manubria from an antheridium of *N. flexilis*.

Text-figure 11. Drawing of a portion of figure 26 showing the flat parenchyma-like layer of cells at the base of five antheridial filaments.

Text-figure 12. Kützing's figure 12f, plate 38. b, primary capitulum; c, secondary capitula; d, tertiary capitula; f, branched filament.

Text-figure 13. A constricted manubrium of *C. baltica* with a round nucleus in each cell. This manubrium bears two primary capitula and is filled with green plastids.

A number of preparations have been obtained in which the secondary capitulum was apparently partitioned into a number of smaller cells, similar to the cells of the antheridial filaments, and this, it seems to me, is a modification of the cases described above where the antheridial filaments were borne directly on the primary capitula. Figure 11 shows a primary capitulum with two secondary capitula, one of which *a*, appears to be partitioned into a number of small cells. This photograph is not very clear and leaves much to be desired, but the presence of the dark nuclei indicates several cells in this secondary capitulum. The other secondary capitulum in this figure bears only one filament, almost equal in diameter to the capitulum, and it is obvious that if such a capitulum were partitioned transversely it would have the appearance of a filament borne directly on the primary capitulum. A similar partitioning of the secondary capitulum is shown in figure 81. The secondary capitulum here shown has evidently been divided up into 11 cells somewhat unequal in size. Whether this is a secondary capitulum or not cannot be regarded as proven, and it is possible that it may be nothing but an antheridial filament borne directly on the primary capitulum whose base is enlarged and irregularly partitioned. A number of similar cases are shown in the filaments designated *R* and *R*, and *1*, *2*, *3*, and *4* in text-figures 6 and 7 in which the bases of filaments arising directly from the primary capitula are much enlarged and irregularly partitioned, and it is very questionable in these cases whether or not the enlarged bases are irregularly partitioned secondary capitula.

VARIATIONS IN NUMBER AND SIZE OF THE PRIMARY CAPITULA AND MANUBRIA

According to Meyen (1839), Kützing (1843), Thuret (1851), Braun (1853), Sachs (1882), Schenk (1882) and Filarszky (1893) each manubrium usually bears one primary capitulum at its apex, thus making eight altogether in the mature antheridium. In a number of carefully dissected antheridia I have observed more than eight large cells directly attached to the manubria which were more or less equal in size and shape to primary capitula. As is shown in tables 1, 2, and 3 of *C. delicatula*, *N. flexilis* and *L. alopercoides* the number of primary capitula in an antheridium may be as high as 17, 16, and 14 respectively. Whether all of these cells are primary capitula is not certain, since in the mature antheridia some of the secondary capitula are almost as large as the primary capitula. In such cases it is difficult to distinguish between small primary capitula and large secondary capitula. However, in the counts in tables 1, 2 and 3 I have tried to eliminate questionable cells as much as possible.

Figure 7 shows two cells of almost equal size attached to one manubrium which appear to be primary capitula, and in figure 10 is shown two similar capitula which were carefully dissected loose from the same manubrium. The capitulum *a* bears a secondary capitulum, *b*, while the other capitulum bears two antheridial filaments. There is a possibility that capitulum, a^1, is a large secondary capitulum, but the great difference in size between it and the secondary capitulum, labeled *b*, makes this view seem improbable. The similarity in size and shape of the pairs of primary capitula shown in figures 7 and 10 suggests that they may possibly have arisen as a result of an equal division of the inner cell in the young antheridium which develops into primary capitula. Figure 14 shows a manubrium with six capitula attached to each other in a group, and their size and shape is so similar that it is impossible to determine whether or not any of them are enlarged secondary capitula. Frequently, when the mature antheridium is dissected, the primary capitula remain together in groups of 2, 3, 4, 5, 6, 7, and 8, or, on the other hand, remain as a group with one manubrium. One is led from this to suspect that figure 14 represents a case where 6 of the eight primary capitula have remained together as a group with one of the manubria. Such is not the case, however, since figure 14 is taken from antheridium number 10L in table 1 of *C. delicatula* which had 17 primary capitula. Figures 7 and 10 were taken from antheridia in which 11 and 13 primary capitula were counted.

In figure 16 is shown an unusual arrangement of capitula which is difficult to interpret. Borne on the apex of the manubrium, *a*, is a very large cell, *b*, from which apparently arise four antheridial filaments. The suggestion of a nucleus at *e* and the vague outlines of a cell wall around it, on the other hand, gives the impression that the filaments arise from a secondary capitulum behind the large cell *b*. On the top of this cell is another capitulum *c*, whose diameter is almost equal to that of the manubrium. The cell marked *d* is likewise unusually large. The relative positions of cells *b* and *c* suggest that they may be secondary and tertiary capitula. However, as noted before, these two cells are almost equal in diameter to the manubrium.

Figure 7 of my preparations is somewhat similar to figure 12, plate 38, by Kützing, in which he shows a manubrium with two primary capitula. As mentioned before, Braun (p. 59) also describes a variation in *C. fragilis* in which manubria bore two and three primary capitula. In *N. syncarpa*, Ernst (1901) describes a number of cases of what he terms pseudo-hermaphroditic plants in which capitula and antheridial filaments are developed in the oogonium, and in figure 33, plate 3, he shows a group of six cells which he calls manubria, primary and secondary capitula. The secondary capitula in this figure are considerably larger than the primary capitula, and the group of cells as a whole have an appearance somewhat as shown in figures 18 and 19 of my preparations.

An unusually good illustration of how the number of primary capitula is increased is shown in figure 18. The manubrium in this figure bears primary capitula at two points instead of only at its apex as in figures 2, 9, and 52. This figure was taken from an antheridium of *C. delicatula* in which were found 16 primary capitula. In this figure may be seen six large cells that have the characteristic appearance of primary capitula. Capitula numbers 3 and 6 are unquestionably attached to the manubrium and numbers 1 and 4 look as if they might have arisen from two divisions of capitulum number 3. The positions of numbers 2 and 5 suggest possibly their origin from capitulum number 4. However, as noted in figures 7, 10, and 14, these extra primary capitula may possibly be enlarged secondary and tertiary capitula; yet the contrast in size between the normal secondary capitulum at *a* and these extra primary capitula is so great that it is hard to conceive of their being the same. Nevertheless, there is no question but what the cells numbered 3 and 6 are primary capitula, and that the development of cells at more than one point on the manubrium leads to an increase in the number of primary capitula above the number eight. Figure 19 shows another manubrium with two large primary capitula directly attached to it, and two other equally large cells which appear as if they may have subsequently arisen from capitulum number 3.

The manubria are similarly subject to variations in size and number. The usual number of manubria in the antheridium is eight, but I have observed a few cases in *C. delicatula* in which the number was increased to 11 and 12 as is shown in table 1. Such variations are very scarce, and I have observed only four antheridia in which this had occurred. The origin of these extra manubria probably occurs in the 16 and 24 cell stage of the antheridium. I have observed a few antheridia in these stages in which the outer cell, which subsequently becomes the shield cell, was undergoing division even after the middle and inner cells were fully formed. The result of this division would naturally result in the formation of another cell which if it continued to grow, probably would become a manubrium.

The size and shape of the manubria vary considerably in the same species. Figures 2, 7, 9, 13, 19, and 52 show the usual and more regular shape of the manubrium in *C. delicatula*. In these figures the manubrium is fairly broad at the base, bulges to a slightly greater diameter in the middle, and then tapers gradually to the apex. Figure 18, on the other hand, shows a manubrium almost as large in diameter at the apex as it is long. The base of the manubrium in this figure is obviously less in diameter than the apex. The opposite condition is shown in figure 65 of a manubrium which is fully as broad at the base as it is long. Similar to the one shown in figure 18, this manubrium bore primary capitula at two points, but unfortunately the primary capitulum which was attached at *g* was torn away. Figure 60 shows another manubrium that is almost oval in shape. Capitula were probably attached at *g*. Text-figure 10–10b shows the variations in size and shape of manubria from an antheridium of *N. flexilis*. In this particular antheridium was found a monster manubrium, 10, with an enlarged base, five normal, 10b, and two small manubria, 10a. The two small atrophied manubria bore no capitula or antheridial filaments.

In several mature antheridia of *C. delicatula* I have observed constricted manubria. Figures 53, 54, and 64 show successive stages of constriction. In figure 54 is shown a manubrium in which the constriction furrow is fully half formed through the cell, and in figure 54 the constriction is almost completed. Figure 64 shows a manubrium in which the constriction is complete, and two cells have been produced. The smaller cell *a* was still attached to the larger cell *b* after the mount was made, but by a very light dissection the cells separated easily.

I have found these constricted and divided manubria only in mature antheridia and am at a loss to know at what stage in the growth of the manubrium constriction begins. The manubria shown in figures 53 and 54 were mature and old, and it is doubtful whether constriction in these particular cells would have progressed further. I have likewise been unable to determine whether the constriction of the cell is accompanied by constriction and division of the nucleus. As is shown by Meyen (1839, fig. 17, pl. 12) the manubrium may be multi-nucleate as a result of amitotic divisions, and it would be particularly worth while to determine the distribution and perhaps the division of the nucleus or the nuclei as the manubrium constricts. This is very difficult to observe in manubria such as are shown in figures 53, 54, and 64 since at this mature stage the dense brown granules resulting from degenerating plastids almost completely obscure the nuclei. However, in text-figure 13 is shown a completely constricted manubrium with a globular nucleus in each cell, but it is not evident whether these nuclei resulted from constriction at the time when the manubrium divided or whether amitosis had occurred previously. This latter view is plausible since the manubrium may often be multinucleate, and at the time of division of the manubrium a single nucleus was included in each cell. In none of the constricted manubria found, have I observed capitula and antheridial filaments developed on both of the cells.

BRANCHING ANTHERIDIAL FILAMENTS

Branching of the antheridial filaments is common to all three of the genera examined. A single filament may branch once, twice, or several times. Figure 22 shows a short branch borne at right angles to the main filament, and in figure 27 is shown a filament that has branched dichotomously twice. The filament shown in figure 28 has apparently branched dichotomously three times. The nuclei in these filaments are elongating and becoming somewhat crescent-shaped, preparatory to the formation of antherozoids. In figure 27 the branches arise at angles of approximately forty-five degrees. Often several branches may arise in the same region of the filament as is shown in figures 24, 25, and 26. Figures 25 and 26 show four and five branches which originated in approximately the same region of the filament. The region in figure 26, where these branches appear to originate resembles a broad, flat layer of parenchyma, one cell in thickness. With the view of bringing out in greater detail the cells and their space relation to each other, I have made a text-figure of a portion of this photograph. Text-figure 11 shows the irregularly partitioned region where the branches merge, and the suggestion of a typical parenchyma is very obvious in this region.

The secondary and tertiary capitula often bear only one antheridial filament whose diameter may be as large as that of the capitulum. After a certain period of growth and division this single filament may branch. Figure 23 shows a secondary capitulum *a*, with one antheridial filament, which after growing a short distance branched dichotomously. The secondary capitulum in the figure was slightly injured in mounting, and consequently, has collapsed. Figure 24 shows another secondary capitulum with one filament which has branched three times, and in the region marked *a* there is a suggestion of another branch that started to develop. The filament is bulged out in this region by the presence of three more or less triangularly shaped cells. It is to be noted in figures 23 and 24 as well as in the capitulum c^1 in figure 2 and number 2 in figure 3, that the diameters of the single filaments before branching are as large as that of the secondary and tertiary capitula, on which they are borne. The branches however are only slightly less in diameter than the main filament. Figure 32 shows a secondary capitulum with four antheridial filaments, one of which *a*, after growing a short distance, developed three branches. In figure 31 is shown another secondary capitulum with four filaments. One of the filaments however has developed a branch at its base and in the opposite direction from its apex.

The most unusual and highly branched antheridial filament found is shown in text-figure 9, from an antheridium of *N. flexilis* growing in Red Brook, Scarboro, Maine. The secondary capitulum in this figure bears a single filament which has branched at five different places, forming a typical tree-like structure.

Kützing (1843) has figured branching filaments in *C. pusilla*, and in text-figure 12, I have reproduced his figure 12f, plate 38. In this figure the primary capitulum, *b*, bears three secondary capitula *c*, and one tertiary capitulum *d*. Filaments *e* and *f* after a short period of growth, branched dichotomously. In his description of the antheridial filaments Lindley (1853) remarks (p. 27), "I once thought I saw them forked." In figure 1, plate 9, Thuret (1851) shows a capitulum with three filaments that resembles figure 24 of my preparations. The capitulum shown by Thuret evidently developed a single filament which immediately branched, forming three filaments. This figure, however, is not sufficiently clear to determine with certainty what has happened, but its close resemblance to figures 23 and 25 suggests that he had likewise found branching filaments.

IRREGULAR PARTITIONING OF ANTHERIDIAL FILAMENTS

The usual structure of the antheridial filament is that of an elongated cylinder partitioned at regular intervals with cross walls at right angles to the long axis of the filament. I have frequently observed variations of this structure in which the antheridal filaments were partitioned in almost every conceivable manner. Figure 33 shows a short thick branch on a filament in which the cell walls are apparently parallel, diagonal, as well as transverse to the long axis of the branch. The hyaline walls in aceto-carmine preparations often fail to show in the microphotographs, and some of the cells in figure 33 appear as if they were multinucleate. However each nucleus in this figure lies in a separate cell. The two nuclei in the apex are separated by a wall parallel to the long axis of the branch, and a diagonal wall separates the two nuclei lying below. In the region where the branch is attached to the main filament may be seen four nuclei, two of which lie somewhat beneath the focal plane. The presence of these nuclei suggest in cross section four cells in tetrad arrangement. A clear and sharp wall is visible between the two nuclei that lie in focus. A somewhat similar filament is shown in figure 84. The secondary capitulum in this figure bears two filaments, one of which is very short and thick and irregularly partitionedl Most of the partitions in this figure are transverse and diagonal. to the long axis of the filament. This filament is likewise more than one cell in diameter in certain regions, and I have indicated this by drawing the nuclei of the cells lying below the focal plane. The difficulty of determining the exact relation of one cell wall to another in aceto-carmine preparations such as are shown in figures 76, 77, 78, 82, and 84 makes it hard to draw accurately the position of the walls of the cells in relation to one another in different focal planes; and for this reason I have only drawn the nuclei of the cells lying below the focal plane. As a result, some of the cells appear binucleate. In the cells marked *a* in figure 84, for instance, there is a definite cell wall between the two nuclei, parallel to the plane of the paper, but which would be difficult to show in the drawing.

Figure 34 shows a portion of another filament in which many of the cells appear binucleate, but close examination shows that the nuclei are separated by diagonal and transverse walls. In regions marked *f* in the filament there is a suggestion of the outlines of originally large cells which were subsequently divided up into smaller cells. Figures 76 and 77 show two filaments which were borne singly on secondary capitula and which are equal in diameter to the secondary capitula. These filaments are partitioned in a manner suggestive of a typical parenchyma. In the region marked *X* and *X* the filament shown in figure 77 is three cells in diameter. In the same manner as in figure 84 I have included in the drawing nuclei of cells lying below the focal plane, and as a consequence some of the cells appear multinucleate. In figure 76 all of the cells are filled with more or less mature, coiled antherozoids. As in figure 34, in the regions indicated by *f* there is a suggestion of large cells which have been divided into smaller cells without losing their original outlines. The cell walls in these filaments are parallel and diagonal as well as transverse to the long axis of the filament.

In figures 37 and 50 are shown three antheridial filaments in which portions are normally partitioned by transverse walls, while other portions are irregularly divided in the same manner as described for figures 33, 34, 76, 77, and 84. In the region marked *g* in figure 37 the filament is normally partitioned by transverse walls, while in the remaining portion, the cell walls are for the most part diagonal. Similar irregularities are shown in figure 50. In the right hand filament of this figure the walls are transverse in the regions marked *h*, while between these two regions at *g* the walls are diagonal. The difference in diameter between the normal and irregularly partitioned portions of the filaments is quite striking in these two figures. It is not unusual to find a filament in which normal and irregular partitioning follow at intervals throughout its whole length. Figure 41 and 42 show two antheridial filaments whose basal ends are irregularly divided, and it is to be noted that the diameter of the filament in these regions is nearly twice as great at the apical end where partitioning is normal. The base is fully three eighths times greater in diameter than the apex, and the filaments taper gradually from base to apex.

In figures 29, 35, 40, 45, 46, 47, 48, 78, 79, and 82 are shown proliferations of cells apparently in the region where the filaments have become bent or curved. These round parenchyma-like outgrowths may be found at or near the apex, figures 29, 40, and 82, in the middle, figures 35, 36, 45, 48, 78, and 79, or near the base, figures 47 and 48, of the filament. In figure 29 is shown filament whose apex consists of a knob-like mass of cells, and the appearance of the mass of cells at the end of the filaments in figures 40 and 82 suggests that the ends were bent over and that the growth continued in the bent portion. In the enlarged end of the filament in figure 82 are eleven nuclei, and the apex of the filament in figure 29 consists of approximately ten cells.

A very pronounced proliferation of cells is shown in figure 25. The secondary capitulum in this figure bears three antheridial filaments one of which marked *g* has been broken off and lies partly behind another filament. The longest filament, approximately equal in diameter to the capitulum, has apparently been doubled back on itself in growth, and in this region an unusually large outgrowth of cells has occurred and which is fully twice the diameter of the filament in the plane of the paper. The outgrowth is composed of approximately 18 cells and appears to be divided in three planes. Figures 47, 48, and 79 are somewhat similar to figure 35 in that the outgrowths are apparently more than one cell in thickness. In all of these figures it is obvious that nuclear and cell division has occurred in three planes, and as a consequence masses of cells have resulted which have the appearance of parenchymatous tissues. In figures 36, 45, and 78 on the other hand, the outgrowths of cells are apparently one cell in thickness and do not exceed in diameter the main filament. Moreover, they are normally divided by transverse septa.

In the irregularly partitioned filaments and outgrowths of cells described above, the cell walls apparently tend to set themselves at right angles to those previously formed, it accordance with the law formulated by Hofmeister (1863) and what is commonly spoken of as Sachs' (1877) rule of rectangular intersection. The relation of the cell walls to each other is difficult to see in the microphotographs in plates 1 to 4, for where tissues are transparent, as in the antheridial filaments of the Characeae, we often have in optical section a puzzling confusion of lines whose exact relation to each other is difficult to bring out in microphotography. In figure 39, however, the cell wall is fairly clear.

In this figure is shown two nuclei in a curved portion of a filament which are separated by a somewhat semi-circular wall whose both ends meet the old filament wall at right angles. It is evident in this figure that the curved wall is not a minimal partitioning area, since a straight wall between the nuclei would obviously be of less area.

In the figures shown in plate 14, I have attempted to draw as accurately as possible from aceto-carmine preparations the intersections of the cell walls and their relation to each other in optical section. In figures 76, 77, 78, 81, 82, 84, 87, 88, and 91 may be found several cell walls that are curved so as to meet the previously formed wall at right angles. This is particularly noticeable in the walls which are numbered consecutively in these figures. The walls numbered *1* and *2* in figures 76 and 78 are unusually good illustrations of rectangular intersection, but it is obvious that they are not minimal partitioning areas. In the majority of cases in these figures the partitions appear to meet at acute angles. In the regions marked *o* in figures 76, 77, 81, and 82 where four walls come together they do not meet in a common point or line. As a consequence, short so-called polar furrows (Conklin, 1897) are formed, so that each wall is in contact with two others, and the three meet at an angle of approximately 120 degrees. In the region marked *M* in figure 77 four cells appear to meet in a common line, but close examination shows that the cells are somewhat rounded off and separated from each other by a small intercellular space.

The origin of irregular partitioning of the atheridial filaments, such as is shown in figures 33, 34, 76, 77, 78, 79, 81, 82, and 84, is suggested in figures 54, 68, 69, and 85. As described in a previous paper (1926) and noted by Giesenhagen (1905), Treub (1880) and Debski (1896) (1898), the equatorial plate in nuclear division frequently lies diagonal and even parallel to the long axis of the filament. In figure 70 is shown the terminal cell of a filament in which the equatorial plate lies parallel to the long axis of the filament, and in figure 69 are two early anaphases which are almost parallel to the long axis of the filament. It is obvious in these figures that if a wall transverse to the long axis of the filament is to be formed between these daughter groups of chromosomes the division figures must rotate approximately 90 degrees in the cells. Often the rotation of the division figure is not completed even in late anaphase, and as a result entire filaments may be found in which the daughter groups of chromosomes lie in diagonally opposite corners of the cell. This is well illustrated in figure 55; and if cell walls were to be formed at right angles to the poles of these division figures the filament would doubtless be divided in the same manner as those which are shown in figures 33 and 37 in which the cross walls are more or less diagonal to the long axis of the filament.

Figure 85 is particularly significant, since in the filament here shown may be seen direct evidence of the origin of irregular partitioning. What was originally the basal cell of the filament, *1*, has been divided by a wall parallel to the long axis of the filament into two cells *a* and *b*. The cell *b* is in late telophase, and in the equator of the cell between the daughter nuclei may be seen the beginning of the cell plate. It is obvious that the cell wall which is to follow will divide the cell transversely. The adjacent cell, number 2, is apparently in late anaphase in which the oval chromosomes lie in the ends of the cell. The shortest diameter of this cell is obviously parallel to the long axis of the filament, and the wall that will subsequently be formed between the nuclei will doubtless be across this short diameter. In the wedge-shaped cell number 3, the equatorial plate is transverse to the filament but parallel to the long axis of the cell. The cell marked *4* is in late telophase, and between the daughter nuclei across ths short axis of the cell and parallel to the long axis of the filament may be seen the beginning of the cell plate. Cell number 5 is apparently in late anaphase with the chromosomes in the ends of the narrow cell. If a cell wall is formed across the clear zone between the groups of chromosomes it will be either parallel or diagonal to the long axis of the filament. This filament, as noted before, is particularly significant in that it shows the beginning of irregular partitioning. It is obvious that if the nuclei in cells *1* and *4* continue to divide and cell walls are formed across the short axis of the cell each time, a group of cells will be formed that will resemble a typical parenchymatous tissue. It is highly probable that the unusually partitioned filaments shown in figures 76 and 77 have arisen in this manner. It is to be furthermore noted in figure 85 that the original outlines of the cells are still visible, although they are being divided up into smaller cells.

A number of young antheridial filaments have been found in which there is a suggestion of the origin of the peculiar outgrowths and proliferation of cells shown in figures 29, 35, 36, 40, 45, 47, 48, 78, and 79, and the branches shown in figures 22, 23, 24, 25, 26, 27, and 28. In the regions where the filaments are bent or curved the nuclei often lie in an eccentric position in the cells near the outer periphery of the bend, as is shown in the region marked *a* in figure 38 and in figure 86. The nuclei in this region are somewhat wedge-shaped as a result of the cell being narrower on the inner periphery of the curve. When such nuclei divide, the result will often be what is shown in figure 90. In this figure is shown five cells in late anaphase in which the chromosome groups lie at the ends of the long axis of the cells, and it is evident that the long axis of the cells is transverse to the filament. As a consequence, if the cell walls that are subsequently developed are formed across the long axis of the cells they will doubtless be parallel to the long axis of the filament. Figure 91 shows a portion of a curved filament in which this has apparently occurred. The curved portion of the filament is two cells across, and if the outer cells of this portion continue to divide an outgrowth of cells such as is shown in figures 35, 40, 45, 46, and 47 will probably be the result.

What was originally the central cell of a curved portion of a filament may often be found to be abnormally divided, while the rest of the cells are normal in every respect. In figures 39 and 88 the original central cell is much larger than the other cell, and partitioned by a somewhat semi-circular wall, meeting the old longitudinal wall of the filament at right angles. A slight modification of this is shown in figure 87 where the curved partition meets both the transverse and longitudinal wall of the filament. If the nuclei and cells marked *a* continue to grow and divide in a direction at right angles to the main filament it is obvious that a branch-like outgrowth will be formed. Figure 89 shows what appears to be the beginning of a branch, and it is probably that it, as well as some of the branches shown in figures 22, 23, 24, 25, 26, 27, and 28 may have arisen in this manner. It is clear, however, from figures 22, 23, 27, and 28 that branches do not only originate in regions where the filaments are bent or curved, since the branches here shown are borne at various angles on straight filaments. It is probable that they have arisen through some changes in the plane of nuclear and cell division. In figure 38 is shown a portion of a filament, one cell of which has been divided parallel to the long axis of the filament. The cell wall between the nuclei is not visible in the photograph, but as seen directly under the microscope it lay somewhat diagonally placed between the two nuclei. It is to be noted in this figure that the diameter of the filament although not irregularly partitioned, is comparatively large up to the region where the two nuclei lie, and from this point on it begins to taper gradually towards the apex. It is highly probable that if the nuclei of the two cells described above continue to grow and divide branches or proliferation of cells may occur at right angles to the filament.

VARIATIONS IN SIZE OF CELLS AND NUCLEI OF ANTHERIDIAL FILAMENTS

It is evident from examination of the figures of irregularly divided filaments that numerous differences in the size of cells and nuclei occur. In figures 33, 34, 35, 45, 47, and 48 the cell walls are not sufficiently clear to determine the exact boundaries of the individual cells, but in figures 37, 50, 76, and 84 the boundaries are more distinct. The cells marked *a* in figures 76, 77, 81, and 84 are unusually large in comparison with the cells marked *b*. Likewise the cells in the irregularly partitioned portions of the filaments shown in figures 37 and 50 are considerably larger than the normal cells in the regions marked *h*. In the outgrowths of cells shown in figures 79, and 82 the sizes of the cells marked *a* are considerably larger than those labeled *b*.

In contrast to the irregularly divided filaments shown in figures 33, 34, 37, 50, 76, 77, 81, 84, and 85, figures 20 and 83 show filaments that are not partitioned at all, and consist of a single long cell. Figure 20 shows a secondary capitulum *a*, with two short filaments *1* and *2*. One of these filaments is very short and appears as an oval cell, while the other filament in three-fourths as long as the manubrium. The other normal filaments in this figure are filled with mature coiled antherozoids. The secondary capitulum in figure 83 bears three filaments, two of which, *a* and *b*, have no cross walls. The length of the cell marked *a* is fully as great as 14 cells of the third normally partitioned filament. Small (1921, figure 934) describes similar long unsegmented filaments in *C. fragilis*.

In filaments that are normally segmented or partitioned may be found cells that are several times larger than the normal size. Such cells may occur at the base, apex, or in the middle of the filament. Figure 43 shows a secondary capitulum, *3*, which bears one filament, the first cell, *2*, of which is fully as long as four of the normal adjacent cells. In figure 80 is shown a long cell at the end of a filament. A similar cell is shown in figure 44 with the exception that it is bent at right angles into the shape of a boot. In the region where the cell is curved, it has divided, forming a small cell which constitutes the heel of the boot. Figure 46 shows the middle portion of a filament that is regularly divided by transverse walls, but in which three of the cells are unusually large in comparison with the other cells. The central portion of another filament is shown in figure 92, in which the cells marked *a* and *b* are fully four times as large as the adjacent cells.

In all of these figures described above the size of the nuclei varies with the size of the cells. The nuclei in the large and small cells marked *a* and *b* in figures 77, 79, 81, 82, and 85 correspond to the size of these cells. Similarly, the unusually large cells described in figures 20, 43, 44, 46, 80, 83, and 92 have correspondingly large nuclei.

Irregularity in the partitioning of the filaments, the development of outgrowths, and the variations in size of cells described above do not apparently, to a certain extent, affect the transformation of the cells into antherozoids. Figures 37, 50, and 76 show irregularly divided filaments whose cells are filled with more or less mature, coiled antherozoids. The size of the antherozoids appears to vary with the size of the cells, and in figures 37 and 50 particularly, may be seen antherozoids of various sizes. In the regions indicated by *g* and *h* in these figures the antherozoids appear normal, while in the irregularly partitioned portions there is great diversity in size. In the cell marked *a* in figure 50, for instance, is an antherozoid which is fully twice as large as the ordinary size. Directly beneath it in the cell *b* may be seen an unusually small antherozoid, which shows very faintly in the photograph. The antherozoids in the large cells in figure 76 are unusually large in comparison with those in the small cells.

This difference in size of the nuclei and antherozoids has apparently come about through irregularities in the distribution of the chromosomes in mitosis, as is shown in figures 56, 57, and 71. Figure 71 is an anaphase stage in which all chromosomes with the exception of two lie at one end of the cell. Near the apical end of the cell lies one chromosome, and in the equator is another smaller chromosome, Later anaphase stages are shown in figures 56 and 57. In the cell marked *1* in figure 56, of *N. flexilis*, a single chromosome lies at one pole of the cell, while the remaining eleven chromosomes lie at the other pole. The late anaphase group of chromosomes do not lie in the same focal plane in the cell, and consequently the single chromosome is not as clear in the photograph as could be desired. In the apical cell of the filament in figure 57 is shown a similar irregularity in chromosome distribution in which two short chromosomes lie at one pole and the rest of the chromosomes at the other pole of the cell.

These irregularities in distribution of the chromosomes lead to the formation of larger and smaller nuclei, as is illustrated in figures 59, 72, and 73. The nuclei numbered 1, 3, 4, 5, 6, and 7 in figure 59 are unusually small, while the nuclei in the adjacent cells are very large. Similarly, the nuclei numbered *1* in figures 72 and 73 are minute in size when compared with those in adjacent cells, and they probably contain the chromatin from one or two chromosomes at most. No nuclei were visible in the cells numbered 2 and 3, and it is probable that they have degenerated because of their small size.

Many cells in telophase before cell plate formation, have been found which were multinucleate, as are shown in figures 58, 67, and 68. The cells marked *a* in these figures each have two fairly large and a small nucleus. In each of the cells marked *b* in figure 58 is a large and an unusually small nucleus. These small nuclei are doubtless the result of a few chromosomes not being included in the larger telophase nuclei. Mettenius (1845), in figures 1a and 4a of *C. hispida*, shows similar cells with large and small nuclei. It is obvious that when the cell walls are formed between these nuclei, large and small-nucleated cells will result. As a consequence, in spermatogenesis small and large antherozoids will be formed. It is highly probable that the monster antherozoid in cell *a* in figure 50 contains a high number of chromosomes, while the small antherozoid in cell *b* is composed of but 2 or 3 chromosomes at most.

VARIATIONS IN THE NUMBER OF FILAMENTS BORNE ON THE CAPITULA

According to the majority of the students of the Characeae the number of antheridial filaments that are borne on each capitulum varies considerably. Meyen reports 2 to 4, Braun and Migula 3 to 5, Sachs 4, Strasburger 3 to 5, Vines 2 and Halstead 4 filaments on each secondary capitulum. The usual number is four, according to these investigators. I have likewise observed considerable variation in the number of filaments borne on the capitula. In figure 76 is shown a secondary capitulum with only one filament, but it is so abnormal in its partitioning that it must be regarded as exceptional. Figures 11 and 43, however, show secondary capitula with single normal filaments. In figures 30 and 49 the secondary capitula bear two filaments in addition to developing bud-like outgrowths, which will be discussed later. In figure 35 is shown a secondary capitulum with three filaments one of which *g*, was broken off near the base and is partly obscured by another filament. In a few antheridia I have observed secondary capitula on which were formed no antheridial filaments but which developed a number of long bud-like growths such as are shown in figures 51 and 62. Such cases, however, are exceptional.

As Meyen, Braun, and Sachs point out the usual number of filaments borne on the secondary capitula is four. In some antheridia of *C. delicatula* and *N. flexilis* I have found as many as nine filaments on one secondary capitulum. The tertiary capitula in figures 1 and 4 bear two filaments. Capitulum number c^1 in figure 2 bears three, and each of the tertiary capitula marked *1*, *b* and *b* in figures 3, 5, and 6 bear four antheridial filaments. The tertiary capitulum labeled *c* in figure 2 bears five filaments. Although only two filaments are borne on the quaternary capitulum in figure 73, as many as five have also been found on a number of quaternary capitula. In antheridia in which a large number of tertiary and quaternary capitula occur, the number of filaments borne by the secondary capitula is proportionately small. In figure 3, for instance, the secondary capitulum *b* bears only two filaments. This correlation is to be expected, since the tertiary and quaternary capitula take the place of the filaments on the secondary capitulum that might have otherwise developed.

VARIATIONS IN THE NUMBER OF CELLS IN THE ANTHERIDIAL FILAMENTS

The number of cells in mature antheridial filaments varies in the same species and in different species. Martius (1818) reports 60 to 90 cells, Meyen (1827) 20 to 30 and Braun (1853) 60 to 90 in *C. fragilis* and *C. foetida* and 80 to 225 in *N. syncarpa.* In *C. delicatula* I have observed the number to vary from 7 to 120. The short filament numbered 4 in figure 1 is composed of not more than seven cells, and in figures 5 and 6 are shown other short filaments with less than ten. In all of the counts made, mature antheridia were selected whose filaments were undergoing spermatogenesis and in which there was no longer any likelihood of further division. In *N. flexilis* the variation may be from 4 to 210 cells per filament, and *L. alopercoides* likewise shows a great variation, from 10 to 150 cells in mature filaments. The very short filaments in these species are exceptional, and the usual number of cells in normal filaments is very high.

BUDDING OF MANUBRIA AND CAPITULA

Budding of manubria and capitula occurs with considerable frequency in most of the species which I have studied. In figures 61, 63, and 66 are shown bud-like outgrowths on mature manubria of *C. delicatula*. Figure 61 shows a small swelling near the base, and in figure 63 a long bud has developed at the apex of the manubrium. In figure 66 the bud *b*, at the apex of the manubrium, is longer than the primary capitulum *a*, and I have observed two cases where such buds were constricted and finally separated from the manubrium.

Figures 8, 12, 17, 30, 51, 52, and 62 show budding capitula, and it is evident from those figures that budding may occur in tertiary, and secondary, as well as primary capitula. Figures 8 and 52 show well developed buds on two primary capitula. Figure 12 shows a secondary capitulum with a fairly long bud, and in figure 17 the secondary capitulum *a* merely grew into a long tube without the production of filaments or buds. Similar capitula are shown in figures 51 and 62. Figure 51 shows a primary capitulum, *a*, with three secondary capitula numbered *1*, *2*, and *3*. Capitulum number *1* grew into a triangular-shaped cell without the formation of any filaments, while number *2* produced a long bud in addition to developing a fairly long, tapering curved cell. Figure 62 shows another primary capitulum with four secondary capitula, all of which failed to develop antheridial filaments and formed only long buds. The capitulum numbered 4 was injured in mounting, and consequently has a collapsed appearance.

Figures 30 and 75 suggest that the buds may eventually be cut off from the capitulum by a cross wall, forming an oblong cell. In figure 30 the nucleus of the capitulum lies near the wall separating it from the bud, suggesting probably that it has recently divided. The appearance in figure 75 suggests that the buds which are probably cut off from the capitulum may continue to divide, forming several cells. However it is not possible to determine with certainty whether the buds shown in these figures are beginnings of antheridial filaments which were probably arrested in their development, or the result of a renewal of growth of the capitula after mature filaments have been developed. If this latter view is correct, it is obvious that the capitula retain the power to grow and divide up to a late stage of development of the antheridia.

FREQUENCY OF VARIATION

The frequency with which these so-called variations described above occur is shown in tables 1, 2, and 3. In each of the three genera studied, with the exception of Lamprothamnus, a complete record was kept of the number and types of variation in fifty antheridia each of plants growing in the field and laboratory, and the percentages shown in table 4 were computed from this number. Fifty is of course a small number from which to compute a percentage, but the tables, none the less, give a fair average of what might be expected.

In the first column of each of these tables is shown the number of manubria found in each antheridium, and in only one species, *C. delicatula*, was there a variation above the usual number eight. In all of the antheridia of *Nitella* and *Lamprothamnus* examined there were eight manubria, but in *C. delicatula* 8 per cent of the antheridia of laboratory plants had more than eight. It is to be noted that none of the antheridia from field plants showed this variation. The highest number of manubria found in a single antheridium was twelve. In the second column is shown the number of primary capitula in each antheridium. However, as noted before, it is often difficult to distinguish between the largest secondary and the smallest primary capitula, and it is probable that a number of cells listed in the second column may be large secondary capitula. The variation in number of primary capitula above the more usual number eight is the same in *C. delicatula* and *N. flexilis* in which 40 and 44 per cent of the antheridia in tables 1 and 2 had more than eight primary capitula, compared with 20 per cent in *L. alopercoides*. In *N. flexilis* 98 and 96 per cent of the antheridia contained tertiary capitula, as is shown in column 3 as compared with 42 per cent and 54 per cent in *C. delicatula* and 60 per cent in *L. alopercoides*. Fifty-eight per cent of the antheridia of *N. flexilis* contained quaternary capitula, while in *C. delicatula* and *L. alopercoides* the percentages are much lower, 6, 4, and 8 respectively. In *C. delicatula* 46a and 64 per cent of the antheridia had branched filaments, as shown in column 5, as compared with 30 and 34, and 30 per cent in *N. flexilis* and *L. alopercoides*. The highest percentage of antheridia with irregularly partitioned filaments was found in *C. delicatula*, 66 and 64 per cent, while in *N. flexilis* the number is comparatively low. Budding of primary, secondary, and tertiary capitula is common to the three genera, but occurred with more frequency in *N. flexilis*, as is shown in table 4.

No budding of manubria was found in the antheridia of *L. alopercoides*, and in *N. flexilis* and *C. delicatula* the number of cases found was very small. Similarly, the number of antheridia in which primary capitula directly bearing antheridial filaments are found is low. In *C. delicatula* 22 and 20 per cent of the antheridia contained primary capitula that bore one or more filaments, while in *N. flexilis* and *L. alopercoides* only 16 and 20, and 6 per cent of the antheridia had similar primary capitula.

All of the antheridia recorded in tables 1, 2, and 3, with the exception of numbers 9f, 29f, 47f, and 22L in *C. delicatula* and 33 in *L. alopercoides*, showed some of these so-called variations. The highest number of primary capitula, 17, was found in antheridium number 11L of *C. delicatula*, and one antheridium, number 32f of *N. flexilis* has 38 tertiary capitula. Antheridia numbers 36L and 47f of *N. flexilis* contained as many as 9 quaternary capitula, and the highest number 14, of budding capitula was found in antheridium number 36f of *N. flexilis*.

TABLE I

Frequency of variations in C. delicatula[1]

An. no.	M.		P. C.		T. C.		Q. C.		B. F.		Irr. Pt.		B. C.		B. M.		P.C.F.		N.T. of V.	
	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.
1	8	8	8	8	0	0	0	0	0	1	3	4	0	0	0	0	0	0	1	2
2	8	8	9	10	0	2	0	0	1	5	2	0	0	0	0	0	0	0	3	3
3	8	8	8	12	0	3	2	1	4	0	0	3	0	0	0	0	0	0	2	4
4	8	8	13	11	2	0	0	2	0	3	0	0	0	0	0	2	1	0	3	4
5	8	8	11	9	5	0	0	0	3	8	1	0	0	2	0	1	0	0	4	4
6	8	8	8	13	0	0	0	0	0	0	0	0	1	0	0	2	0	0	1	2
7	8	8	8	8	0	4	0	0	6	8	0	0	0	0	1	0	0	0	2	2
8	8	8	8	8	0	2	0	0	2	0	0	5	0	0	3	0	0	0	2	2
9	8	8	8	8	0	3	0	0	0	6	0	0	0	0	0	0	0	0	0	2
10	8	8	11	17	5	0	3	0	1	2	3	5	0	0	0	0	0	0	5	3
11	8	8	9	11	0	4	0	0	0	5	3	3	5	0	0	0	0	0	3	4
12	8	9	10	8	0	0	0	0	3	1	0	4	0	0	0	0	0	0	2	3
13	8	8	9	8	6	3	0	0	2	4	2	4	0	6	0	0	0	0	4	4
14	8	8	8	8	0	0	0	0	3	2	2	2	0	0	0	0	0	0	2	2
15	8	11	8	9	0	0	0	0	0	5	1	3	1	0	0	0	0	0	2	4
16	8	8	12	12	5	3	0	0	4	1	0	3	0	0	0	0	1	0	4	4
17	8	8	13	11	0	2	0	0	0	3	4	5	0	0	0	0	0	0	2	4
18	8	9	8	10	0	3	0	0	0	0	6	4	0	0	0	0	0	0	1	4
19	8	8	11	8	3	0	0	0	0	3	3	6	0	0	0	0	0	1	3	3
20	8	8	8	8	1	0	1	0	1	0	0	2	0	0	0	0	1	2	4	2
21	8	8	8	8	2	4	0	0	0	2	3	0	1	0	0	0	0	0	3	2
22	8	8	10	8	3	0	0	0	0	0	1	0	0	0	0	0	0	0	3	0
23	8	8	9	8	0	2	0	0	0	1	4	0	0	1	0	0	0	0	2	3
24	8	8	8	13	0	0	0	0	4	0	0	0	0	0	0	0	2	0	2	1
25	8	8	10	8	0	1	0	0	0	0	2	0	0	0	0	0	0	1	2	2
26	8	8	9	14	2	0	0	0	1	5	1	0	3	1	0	0	0	0	5	2
27	8	12	8	8	4	3	0	0	0	4	0	3	2	0	0	0	0	0	2	4
28	8	8	9	8	7	2	0	0	0	1	2	0	0	1	0	0	0	0	3	3
29	8	8	8	8	0	1	0	0	0	0	0	0	0	6	0	0	0	0	0	2
30	8	8	8	8	0	0	0	0	3	0	3	0	0	0	0	0	0	1	2	1
31	9	8	12	9	2	0	0	0	0	2	4	1	0	0	0	0	0	0	4	3
32	8	8	15	11	0	1	0	0	0	1	2	4	0	2	0	0	1	0	3	5
33	8	8	11	8	4	0	0	0	4	2	0	0	4	0	0	0	2	1	5	2
34	8	8	8	12	0	0	0	0	3	0	0	1	0	1	0	0	0	3	1	4
35	8	8	8	8	0	1	0	0	2	1	0	2	0	0	0	0	0	0	1	4
36	8	8	8	8	2	6	0	0	3	0	0	0	0	0	0	0	1	0	3	1
37	8	8	11	8	4	8	0	0	0	0	0	2	0	0	0	0	2	0	3	2
38	8	8	8	8	0	1	0	0	0	2	0	5	0	2	0	0	0	0	0	4
39	8	8	9	8	6	0	0	0	0	3	2	0	0	1	0	0	0	1	3	2
40	9	8	8	14	0	0	0	0	0	3	3	1	0	0	0	0	0	1	2	4
41	8	8	8	12	0	2	0	0	3	6	2	0	0	0	0	0	2	1	2	4
42	8	8	8	8	1	3	0	0	0	0	0	0	1	0	0	0	0	0	2	1
43	8	8	8	8	2	0	0	0	2	1	5	0	0	0	0	0	1	0	4	1
44	8	8	11	8	0	0	0	0	0	1	2	2	0	0	0	0	0	0	2	2
45	8	8	8	9	3	0	0	0	0	4	3	0	1	0	0	0	0	0	3	2
46	8	8	8	10	0	4	0	0	1	0	1	6	0	0	0	0	0	0	2	3
47	8	8	8	8	0	2	0	0	0	0	0	2	0	0	0	0	0	2	0	2
48	8	8	8	11	4	1	0	0	3	0	0	0	2	0	0	0	0	0	3	2
49	8	8	8	8	0	3	0	0	0	2	0	6	2	4	0	0	0	0	1	4
50	8	8	8	8	0	0	0	0	1	0	1	2	0	3	0	0	1	0	3	2

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[1] An. no., number of antheridium; M, number of manubria per antheridium; P.C., number of primary capitula; T.C., number of tertiary capitula; Q.C., number of quaternary capitula; B.F., number of branching filaments; Irr. Pt., number of irregularly partitioned filaments; B.C., number of capitula with buds; M.C., number of manubria with buds; P.C.F., number of primary capitula directly bearing antheridial filaments; N.T. of V., number of types of variations in each antheridium; f., from field plants; l., from laboratory plants.

TABLE 2

Frequency of variations in N. flexilis

An. no.	M.		P. C.		T. C.		Q. C.		B. F.		Irr. Pt.		B. C.		B. M.		P.C.F.		N.T. of V.	
	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.
1	9	8	8	8	5	4	0	1	0	1	0	0	0	1	0	0	0	0	2	4
2	8	8	8	8	8	2	0	2	0	0	0	0	1	1	1	0	1	0	4	3
3	10	9	8	8	6	3	0	0	0	0	0	0	4	1	0	0	0	0	3	3
4	8	9	8	8	11	6	1	0	0	0	0	0	4	0	0	0	0	0	3	2
5	8	8	8	8	8	4	2	0	2	0	0	2	0	0	0	0	0	0	3	2
6	11	8	8	8	12	15	6	3	2	0	1	0	2	0	0	0	0	0	6	2
7	8	9	8	8	16	12	3	8	0	0	0	1	0	0	0	0	0	0	2	4
8	12	15	8	8	20	11	0	1	2	1	1	0	0	1	0	0	0	0	4	5
9	8	12	8	8	7	4	0	1	2	3	4	0	2	8	0	0	3	0	4	5
10	8	8	8	8	12	2	0	3	0	2	0	0	0	2	0	0	3	1	2	5
11	8	8	8	8	8	6	2	0	0	4	4	0	0	1	0	0	0	0	3	3
12	14	12	8	8	13	5	0	3	0	0	0	0	2	1	2	0	0	0	4	4
13	8	10	8	8	7	22	0	0	0	0	0	0	0	0	0	0	0	4	1	3
14	9	8	8	8	15	8	4	0	1	1	1	0	3	1	1	0	0	0	7	3
15	8	8	8	8	14	3	3	0	1	1	0	0	3	0	0	0	0	2	4	3
16	8	9	8	8	8	9	0	0	0	1	0	2	2	0	0	0	0	0	2	4
17	8	8	8	8	14	12	6	1	0	0	0	1	0	0	0	0	0	1	2	4
18	8	8	8	8	12	16	0	2	3	0	0	1	4	0	0	0	0	0	3	3
19	8	14	8	8	15	8	8	7	0	1	0	0	3	4	0	1	0	1	3	7
20	13	8	8	8	19	20	3	12	0	0	0	0	0	3	0	0	0	0	3	3
21	8	9	8	8	12	14	0	0	0	0	1	0	4	2	0	0	0	0	3	3
22	8	8	8	8	23	16	1	0	0	1	0	1	2	1	0	0	2	0	4	4
23	9	11	8	8	9	12	0	4	0	0	0	0	0	5	0	0	0	0	2	4
24	8	8	8	8	7	11	5	6	0	0	0	0	5	0	0	0	1	0	4	2
25	16	8	8	8	7	8	0	2	1	0	0	0	2	0	1	0	0	0	5	2
26	8	8	8	8	12	7	1	1	0	0	0	0	0	0	0	0	0	0	2	2
27	11	13	8	8	8	5	8	5	0	0	0	0	1	0	0	1	0	0	3	4
28	8	11	8	8	10	28	2	3	0	0	0	0	5	0	0	0	0	0	3	3
29	8	8	8	8	13	19	1	4	0	0	0	0	1	0	0	2	0	0	3	3
30	9	8	8	8	8	6	4	0	0	1	0	0	2	0	0	0	0	0	4	2
31	14	12	8	8	11	4	0	0	0	0	0	0	6	4	0	0	2	0	4	3
32	9	16	8	8	38	15	0	0	0	0	0	0	0	0	0	0	0	0	2	2
33	10	8	8	8	5	3	2	0	1	0	0	0	0	0	0	0	0	0	4	1
34	9	8	8	8	12	18	4	0	0	0	0	0	0	0	0	0	0	0	3	1
35	8	8	8	8	8	20	2	3	1	0	0	0	0	1	0	0	0	0	2	2
36	8	8	8	8	17	14	1	9	0	0	0	0	14	0	0	0	0	0	3	2
37	16	9	8	8	12	3	4	4	0	0	5	0	2	0	0	0	0	0	5	3
38	13	10	8	8	0	12	0	2	1	0	0	1	5	6	0	0	1	0	4	5
39	8	12	8	8	5	13	7	3	0	0	0	0	0	8	0	0	1	0	3	4
40	8	8	8	8	18	7	5	0	4	0	1	0	4	16	0	0	0	1	5	4
41	10	8	8	8	14	0	0	1	0	0	0	0	0	0	0	0	0	2	2	2
42	8	8	8	8	5	0	0	0	0	2	2	0	0	0	0	0	0	0	2	1
43	9	8	8	8	8	12	0	0	0	1	0	0	7	3	0	0	0	0	2	3
44	9	10	8	8	7	22	8	0	2	0	0	0	0	0	0	0	0	0	4	3
45	8	11	8	8	9	5	3	0	0	1	0	0	0	0	0	0	0	0	2	3
46	8	10	8	8	10	8	0	4	1	0	3	2	0	0	0	0	0	0	3	4
47	8	9	8	8	11	21	9	6	3	0	0	1	6	0	0	0	0	0	4	4
48	8	8	8	8	6	18	6	6	0	2	0	0	1	0	0	0	0	4	3	4
49	8	8	8	8	4	5	9	1	0	4	0	1	4	0	0	0	0	2	3	5
50	8	8	8	8	9	6	0	0	0	2	0	0	3	1	0	0	0	1	2	4

TABLE 3

Frequency of variations in L. alopercoides

An. no.	M.	P.C.	T.C.	Q.C.	B.F.	Irr. Pt.	B.D.	B.M.	P.C.F.	No. of T.V.
1	8	8	3	0	4	6	5	0	0	4
2	8	8	2	0	3	5	4	0	0	4
3	8	8	0	0	2	2	1	0	0	3
4	8	8	3	0	0	1	3	0	0	3
5	8	8	4	0	3	4	2	0	0	4
6	8	8	1	0	0	2	0	0	0	2
7	8	8	0	0	1	4	0	0	0	2
8	8	8	4	0	0	2	0	0	0	2
9	8	9	2	0	0	4	2	0	0	4
10	8	10	0	0	0	3	0	0	0	2
11	8	8	0	0	0	2	0	0	0	1
12	8	11	3	0	0	0	0	0	1	3
13	8	14	0	0	0	5	0	0	0	2
14	8	8	0	0	1	0	0	0	0	1
15	8	8	3	0	0	0	3	0	0	2
16	8	8	2	0	0	0	2	0	0	2
17	8	9	3	0	0	0	0	0	0	2
18	8	11	0	0	0	3	4	0	0	3
19	8	8	3	0	0	0	8	0	0	2
20	8	12	2	0		2	3	0	0	4
21	8	8	0	0	0	3	3	0	0	2
22	8	8	3	0	0	0	0	0	0	1
23	8	8	0	0	2	0	0	0	0	1
24	8	8	3	0	0	0	0	0	0	1
25	8	8	0	0	0	6	5	0	0	2
26	8	8	2	0	0	3	4	0	0	3
27	8	8	2	0	0	0	0	0	0	1
28	8	8	2	0	0	0	3	0	0	2
29	8	8	2	0	0	0	0	0	0	1
30	8	8	1	0	0	0	0	0	0	1
31	8	8	0	0	0	3	0	0	0	1
32	8	8	0	0	0	1	0	0	0	1
33	8	8	0	0	0	0	0	0	0	0
34	8	8	2	0	0	5	0	0	0	2
35	8	8	3	0	4	0	6	0	0	3
36	8	8	0	1	3	0	3	0	0	3
37	8	8	1	2	0	4	0	0	0	3
38	8	8	2	0	0	4	0	0	0	2
39	8	9	0	0	0	0	0	0	0	1
40	8	8	1	0	2	0	0	0	0	2
41	8	8	0	3	1	3	0	0	0	3
42	8	10	0	0	0	0	2	0	1	3
43	8	11	2	0	0	5	1	0	0	4
44	8	12	3	0	1	0	0	0	0	3
45	8	8	4	0	0	3	0	0	0	2
46	8	8	0	0	0	7	2	0	0	2
47	8	8	0	0	1	0	1	0	0	2
48	8	8	2	4	3	0	0	0	2	4
49	8	9	1	0	4	2	0	0	0	4
50	8	8	0	0	0	0	0	0	0	0

In *C. delicatula* one antheridium contained 8 branched filaments, and 7 irregularly partitioned filaments were found in a single antheridium of *L. alopercoides*.

The number of different types of variations in the individual antheridia is fairly high. The last column in tables 1, 2, and 3 shows the number of different types of variations which were found in single antheridia. Antheridia numbers 14 f and 19L show seven of the nine recorded variations. As is shown in tables 1, 2, and 3, three, four and five types of variations per antheridium is the more general number. Although most of the antheridia show some type of variation, the number of single organs that vary in proportion to the total number of such organs in the antheridium is very small. Branching of the antheridial filaments may be taken as an example. The total number of filaments in a single antheridium may often be as high as 200, while 8 was the highest number of branched filaments found in any of the antheridia examined. In this case only four percent of the total number of filaments would be branched.

No attempt has been made in tables 1, 2, and 3 to record the number of secondary capitula. If fully mature antheridia in which the antherozoids are already formed are dissected, the filaments and capitula generally separate, and when these structures thus lie separate it is difficult to distinguish the secondary and tertiary capitula, and only in antheridia where the filaments and capitula are still united with each other is it possible to identify them by their relative positions. Moreover the presence of what seem to be supernumerary primary capitula further complicates the matter. However, in a number of carefully dissected antheridia I have observed that the number of secondary capitula in the antheridium is often correlated with the development of tertiary and quaternary capitula. In antheridia in which there were large numbers of these latter capitula the number of secondary capitula was considerably less than forty-eight, which, according to Braun and Sachs, is the more usual number.

DISCUSSION

In the formation of the antheridium of the Characeae the globular mother-cell divides into two hemispheres by a vertical wall, and each of these two cells is divided into segments by

TABLE 4

Percentage of antheridia in tables 1, 2 and 3 which showed the different types of variations

Species	M.		P.C.		T.C.		Q.C.		B.F.		Irr. Pt.		B.C.		B.M.		P.C.F.	
	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.	F.	L.
C. delicatula	0	8	40	44	42	54	6	4	46	64	66	64	20	24	4	6	22	20
N. flexilis	0	0	40	44	98	96	58	58	30	34	20	20	56	42	8	6	16	20
L. alop.	0		20		60		8		30		44		42		0		6	

another vertical wall at right angles to the first, so that the third cell generation, beginning with the mother-cell as the first generation, of the antheridium consists of quadrants. The third division is horizontal and at right angles to the last two walls, and the antheridium in this stage consists of four lower and four upper octants of a sphere. Each octant further divides into an outer and an inner cell; the latter is again divided in all of the eight octants, so that each octant now consists of an inner, a middle, and an outer cell, making twenty-four cells in the whole antheridium. By unequal growth the outer eight cells become the shield cells, the middle cells the manubria, and the inner cells become the primary capitula. From each primary capitulum is cut off six small cells which become the secondary capitula, and on each of these latter cells are usually formed four antheridial filaments. This method of formation of the antheridium, as described by Braun and Sachs, may be regarded as the type formation, and it is obvious that the order of development of cells is comparatively simple and diagrammatic. In this type formation the shield cells thus represent the fifth, and the manubria and primary capitula the sixth cell generations. The divisions of the primary capitula to form the six secondary capitula result in the seventh generation, while the four antheridial filaments that are usually borne on each secondary capitulum represent the eighth generation of cells from the mother-cell.

The development of antheridial filaments directly on primary capitula, increase in number of primary capitula, and the formation of tertiary and quaternary capitula indicate considerable variation in the number of cell generations between the antheridium mother-cell and the antheridial filament. As pointed out above, the antheridial filament, if borne on the secondary capitulum, represents the eighth cell generation in the antheridium, but it is obvious in such cases where the filament is borne directly on the primary capitulum and by tertiary and quaternary capitula that it may represent the seventh, ninth and tenth generation, respectively, as well. Likewise, in cases where an increase in the number of primary capitula has occurred, as in figures 14, 18 and 19, the secondary capitulum does not always belong to the seventh, but may even be the eighth and ninth generation. Accordingly, it is obvious that the secondary capitulum and antheridial filament may be of the same order of cells in the development of the antheridium. In cases where the antheridial filament is borne directly by the primary capitulum the number of cell divisions, and consequently the number of cell generations, has apparently been suppressed, while in cases where supernumerary primary capitula, tertiary and quaternary capitula are formed the number of cell generations has been increased.

It is not evident from tables 1, 2, and 3 whether the percentage of divergence from type increases with the number of cell generations, since these tables deal with variations in mature antheridia, and moreover, do not give comparative numbers of variable and normal structures in the antheridium. However, I have frequently observed variations from type in the eight- and sixteen-cell stages of the antheridium, but since we are here dealing with the structure of the mature antheridium these variations have been omitted for further study.

The fact that only six of the two hundred and fifty antheridia recorded failed to show some degree of variation from type is significant in that it indicates that the habit of growth of the antheridium of the Characeae, in spite of its simplicity of type, is probably no less variable than that of other less diagrammatically constructed plants. Table 4 shows that tertiary capitula, occurring in 98 and 96 per cent of the antheridia examined, are almost as commonly formed in the antheridia of *N. flexilis* as secondary capitula. However, I have not determined the comparative numbers of secondary and tertiary capitula in a single antheridium, because of the difficulty of differentiating between the smallest secondary and the largest tertiary capitula as they lie separate in the dissected mature antheridium. A careful count of capitula may show that the number of tertiary capitula in a single antheridium is low in comparison with the number of secondary capitula. Tertiary capitula in *N. flexilis*, however, may be regarded, it seems to me, as quite as typical as secondary capitula. In *C. delicatula* branching and irregularly partitioned filaments were found in nearly fifty per cent of the antheridia, but in this case, as noted before, the number of such filaments in a single antheridium is low in comparison with the total number of normal filaments.

The irregularities in the distribution of the chromosomes, the presence of large and small nuclei, and, apparently as a consequence, the formation of large and small antherozoids, as are shown in figures 37, 50, 56, 57. 58, 59, 67, 68, 71, 72, and 73, are variations of another class. The variations discussed above were morphological divergences from type formation of the antheridium, while these are cytological and deal with variations within the individual cells. However, it is apparent that both classes of variations are closely related, since some of the morphological variations, irregular partitioning and branching of the antheridial filaments, for example, may have arisen from variations within the individual cells.

It is obvious that if the large and small antherozoids contain high and low chromosome nunbers, as figures 56, 57, 58, 59, 67, 68, 71, 72, and 73 seem to indicate, and are capable of fertilizing eggs, irregularities in the chromosome number of the zygote and the subsequent sporeling will, consequently, occur. I have observed large and small antherozoids, such as are shown in the cells marked *a* and *b* in figure 50, escape from the antherozoid mother-cells, but whether they are capable of fertilizing eggs and whether such fertilized eggs would be viable is yet to be determined from further study. The irregularities in chromosome distribution and the formation of large and small nuclei are, furthermore, significant, since these nuclear and cell divisions are in somatic tissues and are not concerned with the reduction of the chromosome number, according to Debski (1898), Götz (1899) and Oehlkers (1916). Irregularity in chromosome distribution and the formation of large and small pollen grains occur frequently in pollen mother-cells, particularly in the case of hybrids, but in somatic mitosis the distribution of the chromosomes to the poles of the cells is generally regarded as more regular. Aberrations of the mitotic figure in somatis tissues, however, have been artifically produced in a large number of plants. In root tips and other plant tissues subjected to the influence of ether and chloral hydrate (Nathanson, 1900; Němec, 1904, 1910; Sakamura, 1920), Röntgen rays (Komuro, 1917, 1922, 1924), ultra-violet rays (Takamine, 1923; Schliep, 1923), radium (Mohr, 1919; M. Williams 1925) and low temperature (Borgenstam, 1922) the chromosomes are generally scattered irregularly in the cells and may collect into several groups and organize nuclei of various sizes. The large nucleus marked *a* in figure 68 of my preparations appears somewhat constricted and suggests that it may be undergoing division by amitosis. The appearance of this nucleus as well as that of the two in the cell above is somewhat similar to that figured by Sakamura (1920, figure 57) and by Němec (1904, figs. 17–31) of chloralized cells in which the chromosomes are reconstructing nuclei unequal in size. It may be that the irregularities in mitosis shown in figures 58, 67, and 68 may be caused by some foreign injurious substance in the water in which the plants were growing. These cells, however, are from plants that were growing in a fairly large lake and not in tap water.

These so-called variations were first observed by me in plants from cultures which had been growing two years in the laboratory in New York City tap water which is often chlorinated to keep down the growth of algae and bacteria, and one might suspect that the presence of minute amounts of chlorin may be an influencing factor. However, I have found these variations in the antheridia of different species of Characeae from France, England, New England, the limestone regions of Texas and Mexico, Iowa, Wisconsin, Virginia and Ohio. This, together with the fact that similar variations have been reported from widely separated localities in Europe, is evidence against this view. As is shown in table 4 the percentage of variations on the average is about the same in field and laboratory plants, and the difference between the two is obviously too small to be adequate ground for assuming that they may be the result of any peculiar difference in the water in which the plants were growing.

SUMMARY

In method of development and symmetry the Characeae are perhaps the most diagrammatic of any organism, plant or animal. It is not merely that their radial and metameric organization results in the well proportioned chandelier-like form, but their cellular make-up is so simple as to at once suggest the possibility of mathematical analysis. This regularity of growth, according to Braun and Sachs, extends to the antheridia and oogonia as well. The mature antheridium of the Characeae usually consists of eight outer shield cells, eight manubria, eight primary capitula, forty-eight secondary capitula, and four antheridial filaments borne on each of the latter. This has generally been regarded as the type structure of the antheridium. However, a considerable number of variations from this type structure have been observed, which are discussed and classified into the eight following groups:

1. In addition to primary and secondary capitula, tertiary and quaternary capitula are frequently formed, which in turn bear antheridial filaments.

2. The number of primary capitula and manubria often varies. As many as twelve manubria and sixteen primary capitula have been found in a single antheridium.

3. The antheridial filaments may often branch, sometimes as many as five times.

4. Irregular partitioning of the antheridial filaments is not uncommon. Septa may be formed parallel, diagonal and at right angles to the long axis of the filament.

5. Variations in the number of antheridial filaments borne on each secondary capitulum occur. In *C. delicatula* the number may vary from one to nine.

6. The manubria, primary, secondary and tertiary capitula often form bud-like outgrowths, which are sometimes cut off by transverse septa.

7. The number of cells in an antheridial filament varies to a considerable degree. In a single species the variation may range from five to one hundred and fifty cells.

8. Inequalities in the size of cells and nuclei occur in the antheridial filaments, apparently as a result of irregularities in the distribution of the chromosomes during mitosis. The large and small cells, nevertheless, develop into germ cells, thus forming large and small antherozoids.

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Literature cited

Agardh, C. A. 1826. Über die Anatomie und den Kreislauf der Charen. Nova Acta Acad. Caes.-Leop.-Car. Nat. Curios. **3:** 113–162. pl. 10.

Belling, J. 1921. On counting chromosomes in pollen mother cells. Am. Nat. **55:** 573–574.

Bischoff, G. H. 1828. Die Kryptogamen Gewäsche Deutschlands und der Schweitz 1: Characeen und Equisetum, p. 1–60. pl. 1–6. Nurnberg.

Borgenstam, E. 1922. Zur Zytologie der Gattung *Syringa*. Ark. Bot. **17**^{15}: 1–27. pl. 1.

Braun, A. 1853. Über die Richtungsverhaltnisse der Salfströme in den Zellen der Characeen. Ber. Kongl. Preuss. Akad. wiss. 1853: 45–76.

Campbell, D. H. 1907. A university text-book of botany. 2 ed. London.

Celakovsky, L. 1878. Ueber die morphologische Bedeutung der sog. Sporensprösschen der Characeen. Flora **61:** 49–57, 73–76.

Conklin, E. G. 1897. The embryology of *Crepidula*. Jour. Morph. **13:** 1–226. pl. 1–9.

Debski, B. 1896. Beobachtungen über die Kerntheilung bei *Chara fragilis*. Jahrb. Wiss. Bot. **30:** 227–248. pl. 9, 10.

————. 1898. Weitere Beobachtungen an *Chara fragilis*. Jahrb. Wiss. Bot. **32:** 635–668. pl. 11, 12.

Ernst, A. 1901. Ueber pseudo-hermaphroditimus und andere Missbildungen der Oogonen bei *Nitella syncarpa* (Thuill) Kützing. Flora **88:** 1–36. pl. 1–3.

————. 1904. Die Stipularblätter von *Nitella hyalina* (D.C.) Ag. Vierteljahrs. Nat. Gesell. Zurich **49:** 64–114. pl. 8.

Filarszky, N. 1893. Die Characeen (Characeae L. Cl. Richard) mit besonderer Rücksicht auf die Ungarn beobachteten Arten. Budapest.

Fritzsche, K. J. 1837. Über den Pollen. Mem. Acad. Imp. Sci. St. Petersburg Sav. Etran. **3:** 649–767. pl. 1–13.

Giesenhagen, K. 1896. Untersuchungen über die Characeen. I. Die Wurzelknöllchen der Characeen. Flora **82:** 381–433. pl. 10, f. 1–25.

————. 1897. II. Der Bau der Sprossknoten bei den Characeen. Flora **83:** 160–202. pl. 5, f. 26–42.

————. 1898. III. Der Bau der Sprossknoten. Flora **85:** 19–64. pl. 3, 4, f. 43–59.

————. 1905. Studien über die Zellteilung im Pflanzenreich. Stuttgart.

Goebel, K. 1902. Morphologische und Biologische Bemerkungen. II. Ueber Homologien in der Entwickelung männlicher und weiblicher Geschlechtsorgane. Flora **90:** 279–315. f. 9.

————. 1918. Zur Organography der Characeen. Flora **110:** 344–387. f. 1–21.

Götz, G. 1899. Über Entwickelung der Eiknospe bei den Characeen. Bot. Zeit. **57:** 1–13. pl. 1.

Halstead, D. B. 1879. Classification and description of the American species of Characeae. Proc. Boston Soc. Nat. Hist. **20:** 169–190.

Hofmeister, W. 1863. Zusätze und Berichtigungen zu den 1851 veröffentlichen Untersuchungen der Entwickelung höherer Kryptogamen. Jahrb. wiss. Bot. **3:** 259–293. pl. 8.

———. 1867. Die Lehre von der Pflanzenzelle. Leipzig.

Karling, J. S. 1926. Nuclear and cell division in *Nitella* and *Chara*. Bull. Torrey Club **53**: 319–379. pl. 10–13, f. 1–6.

Kaulfuss, G. F. 1825. Erfahrungen über dass Keimen der Charen, nebst anderen Beyträgen zur Kenntniss dieser Pflanzengattung. Leipzig.

Komuro, H. 1917. On the effect of Röntgen Rays upon the cell and tissue of *Vicia fabe* L. Jour. Phys. Therapy, No. 6.

———. 1922. Preliminary note on the cells of *Vicia faba* modified by Röntgen Rays and their resemblance to tumor cells. Bot. Mag. Tokyo **36**: 41–45.

———. 1924. Cytological and physiological changes in *Vicia faba* irradiated with Röntgen Rays. Bot. Gaz. **77**: 446–452. f. 1.

Kuczewski, O. 1906. Morphologische und biologische Untersuchungen an *Chara delicatula* f. *bulbillifera* A. Braun. Beih. Bot. Centralb. 20^1: 25–75. pl. 2, 3, f. 1–19.

Kützing, F. T. 1843. Phycologia Generalis. Leipzig.

Lindley, J. 1853. The vegetable kingdom. 3 ed. London.

Martius, C. P. F. 1818. Über den Bau und die Natur der Charen. Verhandl. Leop.-Car.-Acad. Naturf., **1**: 181–214. pl. 2, 3.

Mettenius, G. 1845. Beiträge zur Entwickelungsgeschichte der beweglichen Spiralfasern von *Chara hispida* L. Bot. Zeit. **3**: 17–24. pl. 1.

Meyen, F. J. F. 1827. Beobachtungen und Bemerkungen über die Gattung *Chara*. Linnaea **2**: 55–81. pl. 2, 3.

———. 1839. Pflanzenphysiologie 3. Berlin.

Migula, W. 1890–1897. Die Characeen Deutschlands, Oesterreichs und der Schweitz. Rabenhorsts Kryptgamen-flora 5: Die Characeen. Leipzig.

Mohr, O. H. 1919. Microskopische Untersuchungen zu Experimenten über den Einfluss der Radiumstrahlen und der Kältesvirkung auf die Chromatinreifung und das Heterochromosomen bei Dicticus verruccivoruis (♂). Arch. Mikr. Anat. **92**: 300–368. pl. 11–16.

Müller, A. 1907. Beiträge zur Kenntniss der *Chara hispida* Linne und *Chara foetida* Braun. Inaug.-Diss. Zurich, 1907. München, 1907.

Nägeli, C. 1845a. Wachstumsgeschichte von *Delesseria hypoglossum*. Zeit. wiss. Bot. $\mathbf{1}^2$: 121–137. pl. 1.

———. 1845b. Wachstumsgeschichte der Laub-und Lebermoose. Zeit. wiss. Bot. $\mathbf{1}^2$: 138–210. pl. 2–4.

———. 1860. Beitrage zur wissenschaftlichen Botanik 2. Leipzig.

Nathansohn, A. 1900. Physiologische Untersuchungen über amitotische Kerntheilung. Jahr. wiss. Bot. **35**: 48–79. pl. 1, 2.

Nêmec, B. 1904. Ueber die Einwirkung des Chloralhydrats auf die Kern- und Zelltheilung. Jahr. wiss. Bot. **39**: 645–730. f. 1–157.

———. 1910. Das Problem der Befruchtvorgänge. Berlin.

Nonweiler, G. 1907. Morphologische und Physiologische Untersuchungen an *Chara strigosa* Braun. Inaug.-Diss. Zurich, 1907. Borna-Leipzig.

Oehlkers, F. 1916. Beitrag zur Kenntniss der Kernteilung bei den Characeen. Ber. Deut. Gesell. **34**: 223–227. f. 1.

Sachs, J. 1877. Ueber die Anordnung der Zellen in jüngsten Pflanzentheilchen. Verhandl. Phys. Med. Gesell., Wurzburg **11**: 219–242. pl. 5.

————. 1882. Text-book of botany. 2 ed. Oxford.

Sakamura, T. 1920. Expeirmentelle studien über die Zell- und Kernteilung mit besonderer Rucksicht auf Form, Grösse und Zahl der Chromosomen Jour. Coll. Sci. Imp. Univ. Tokyo **39:** 1–221. pl. 1–7.

Schacht, H. 1864. Lehrbuch der Anatomie und Physiologie der Gewäsche 2. Berlin.

Schenk, A. 1882. Handbuch der Botanik. 2. Breslau.

Schleiden, M. J. 1842. Grundzüge zur wissenschaftlichen Botanik 2.

Schleip, W. 1923. Die Wirkung des Ultravioletten Lichtes auf die Morphologischen Bestanteile das Ascariseies. Arch. Zellf. **17:** 289–367. pl. 15. f. 1–24.

Schultz, C. H. 1828. Die Natur der Lebendigen Pflanzen 2. Stuttgart und Tübingen.

Small, J. 1921. A text-book of botany. London.

Sluiter, C. P. 1910. Beiträge zur Kenntniss von *Chara contraria* A. Braun und *Chara dissoluta* A. Braun. Bot. Zeit. **68:** 125–168. pl. 4–8, f. 1–21.

Strasburger, E., Noll, F., Schenk, H., und Karsten, G. 1895. Lehrbuch der Botanik 2d ed. Jena.

————. 1908. A text-book of botany, 3rd Eng. ed. London.

————. 1921. A text-book of botany, 5th Eng. ed. London.

Takamine, N. 1923. On the effect of Ultraviolet Rays upon nuclear division of plants. Bot. Mag. Tokyo **37:** 109–112. pl. 5.

Thurêt, M. G. 1840. Note sur l'anthere du *Chara* et les animalicules qu'elle renferme. Ann. Sci. Nat. **14:** 65–72. pl. 5–8.

————. 1851. Recherches sur les zoospores des Algues et les antheridies des Cryptogams. Ann. Sci. Nat. **16:** 5–39. pl. 1–15.

Treub, M. 1880. Notice sur les noyaux des Cellules végétales. Arch. Biologie **1:** 393–404. pl. 16.

Van Tieghem, P. 1918. Elements de Botanique 2. 5th ed. Paris.

Varley, C. 1849. On *Chara vulgaris*. Trans. Micro Soc. London **2:** 93–104. pl. 14–21.

Vines, S. H. 1898. Elementary text-book of botany. London.

Wallroth, F. G. 1815. De Chara Genere. Annus Botanicus 1815: 157–196.

Warming, E. 1890. Handbuch der systematischen Botanik. Berlin.

Williams, M. 1923. Observations on the action of X-rays on plant cells. Ann. Bot. **37:** 217–223.

Witt, A. 1906. Beiträge zur Kenntniss von *Chara ceratophylla* Wallroth und *Chara crinita* Wallroth. Inaug.-Diss. Zurich, 1906. Borna-Leipzig, 1906.

Explanation of plates

All figures are photographs and drawings of aceto-carmine preparations made with a Zeiss 2 mm. apochromatic objective N.A. 1.30 and compensating oculars 6, 8, and 12. A Leitz Liliput arc light was used as a source of illumination in photographing, and the drawings in plate 5 were made with the aid of a Spencer camera lucida. Approximate magnifications are given with each figure.

PLATE 10

Fig. 1. A secondary capitulum, *a*, of *C. delicatula* which bears three antheridial filaments, *1*, *2*, and *3*, and one tertiary capitulum, *b*, with two filaments, *4* and *5*. In each cell of the antheridial filaments is a mature coiled antherozoid. × 650.

Fig. 2. A manubrium of *C. delicatula* with one primary capitulum, *a*. The secondary capitulum, *b*, bears three antheridial filaments, *6*, *7* and *8*, in addition to two tertiary capitula, *c* and c^1. The tertiary capitulum *c* bears five filaments. One filament is borne directly by the primary capitulum. × 400.

Fig. 3. A secondary capitulum, *b*, of *C. delicutula* which bears three tertiary capitula, *1*, *2* and *3*, in addition to two antheridial filaments. × 600.

Fig. 4. A secondary capitulum of *C. delicatula* with one tertiary capitulum and three antheridial filaments. × 650.

Figs. 5 and 6. Secondary capitula of *C. delicatula* with one tertiary capitulum. The secondary and tertiary capitula each bear four antheridial filaments. × 650, 700.

Fig. 7. A manubrium of *N. flexilis* with two primary capitula almost equal in size. One of the capitula bears an antheridial filament directly attached. × 650.

Fig. 8. A primary capitulum of *C. delicatula* with one antheridial filament. The capitulum has a bud-like outgrowth near the apex. × 700.

Fig. 9. A manubrium of *C. fragilis* with one primary capitulum, *a*, which bears two antheridial filaments in addition to a secondary capitulum. × 600.

Fig. 10. Two primary capitula, *a* and a^1, of *C. delicatula* which were borne on one manubrium. One of the primary capitula bears two antheridial filaments. × 650.

Fig. 11. A primary capitulum of *C. delicatula* with two secondary capitula, one of which, *a*, has been divided up into a number of cells. The other secondary capitulum bears a single antheridial filament. × 600.

Fig. 12. A secondary capitulum of *C. contraria* with a long bud or protuberance near the apex. × 800.

Fig. 13. A manubrium, *a*, of *C. delicatula* from which the primary capitulum *b* was dissected. This primary capitulum bears one antheridial filament. × 500.

Fig. 14. A manubrium of *C. delicatula* with six primary capitula. × 300.

Fig. 15. A primary capitulum of *C. delicatula* with two secondary capitula, one of which is almost equal in size to the primary capitulum. × 400.

Fig. 16. A manubrium, *a*, of *C. delicatula* with a large primary capitulum-like cell, *b*, Cells *c* and *d* by reason of position correspond to secondary and tertiary capitula, although their diameters are almost equal to that of the manubrium. × 700.

Fig. 17. Two secondary capitula of *C. delicatula*, one of which bore no antheridial filaments and merely grew into a long tub-like cell. × 450.

PLATE II

Fig. 18. A manubrium of *C. delicatula* which bears primary capitula at two points. Cells *1*, *2*, *3*, *4*, *5* and *6* are almost equal in size and all appear to be primary capitula. × 700.

Fig. 19. A manubrium of *N. flexilis* with two primary capitula, *3* and *4*. Cells *1* and *2* are almost equal in size to the primary capitula. × 675.

Fig. 20. A manubrium of *C. delicatula* with a secondary capitulum, *a*, which bears two short antheridial filaments, *1* and *2*, without cross walls. The cells of the other antheridial filaments are filled with mature antherozoids. × 650.

Fig. 21. A manubrium of *L. alopercoides* with a primary capitulum which bears an antheridial filament, *1*, directly. × 700.

Fig. 22. A portion of an antheridial filament of *C. delicatula* which bears a short branch at right angles. × 700.

Fig. 23. A secondary capitulum, *a*, of *C. delicatula* which bears one antheridial filament. This filament branches dichotomously after a short period of growth. × 700.

Fig. 24. A similar secondary capitulum of *C. delicatula* with one filament which divided into three branches. The filaments in these two figures are equal in diameter to the secondary capitula. × 700.

Fig. 25. An antheridial filament of *C. delicatula* with four branches originating in the same region. × 600.

Fig. 26. A secondary capitulum of *L. alopercoides* with five antheridial filaments which merge together at the base forming a flat parenchyma-like layer of cells. × 575.

Fig. 27. A mature antheridial filament of *C. delicatula* which branches dichotomously twice. × 650.

Fig. 28. An antheridial filament of *C. delicatula* which has apparently branched dichotomously three times. × 325.

Fig. 29. A knob-like outgrowth of cells at the end of an antheridial filament of *C. delicatula*. × 800.

Fig. 30. A secondary capitulum of *C. delicatula* with two antheridial filaments and a large bud-like outgrowth, which has been cut off from the capitulum by a cross wall. × 500.

Fig. 31. A secondary capitulum of *N. delicatula* which bears four antheridial filaments, one of which has developed a branch at its base and in the opposite direction from its apex. Each cell of the filaments is filled with a coiled, mature antherozoid. × 525.

Fig. 32. A secondary capitulum of *C. zeylanica* with four antheridial filaments, one of which, *a*, developed three branches. The cells of the filaments are filled with mature antherozoids. × 625.

Fig. 33. A short, thick, irregularly partitioned branch or outgrowth of an antheridial filament of *C. delicatula*. × 1250.

PLATE 12

Fig. 34. A portion of an irregularly partitioned antheridial filament of *C. delicatula*. The regions indicated by *f* are perhaps the outlines of large original cells which have subsequently been divided up into smaller cells, × 2000.

Fig. 35. A secondary capitulum of *C. delicatula* with three antheridial filaments, one of which has developed a large parenchyma-like outgrowth of cells in the region where it is curved. × 800.

Fig. 36. An antheridial filament of *C. delicatula* with a small outgrowth of cells in the region where it is curved. × 1100.

Fig. 37. The terminal portion of an irregularly partitioned antheridial filament of *C. delicatula* with large and small antherozoids in the cells. The filament is regularly partitioned by transverse septa in the region marked *g*. × 1100.

Fig. 38. A portion of an antheridial filament of *C. delicatula* in which the nuclei of the cells in the region of curvature are somewhat wedge-shaped. × 1000.

Fig. 39. Curved portion of an antheridial filament of *C. delicatula*. What was apparently the central cell in this curved portion has been divided by a semicircular wall into two cells. This new wall meets the old wall of the antheridial filament at right angles. × 1000.

Fig. 40. An outgrowth of cells near the end of an antheridial filament of *C. vulgaris*. × 475.

Figs. 41 and 42. Antheridial filaments of *C. delicatula* which are irregularly partitioned at the base but normal at the apex. The filaments taper gradually from base to apex. × 650.

Fig. 43. A secondary capitulum, *3*, of *N. flexilis* which bears one antheridial filament, the first cell of which, *2*, is fully four times as long as the remaining cell. The cells are undergoing metamorphosis into antherozoids. × 650.

Fig. 44. A large boot-shaped apex of an antheridial filament of *C. delicatula* which consists of two cells which are enormous in size compared with other cells of the filament. × 1250.

Fig. 45. A short tubular outgrowth or branch on a filament of *C. delicatula*. × 1000.

Fig. 46. A portion of a filament of *L. alopercoides* with three large cells in the center. × 1000.

Fig. 47. A short antheridial filament of *C. delicatula* with an outgrowth of cells near the base. × 600.

Fig. 48. A magnified view of the outgrowth shown in figure 47. × 1000.

Fig. 49. A secondary capitulum of *C. delicatula* with a short bud in addition to two antheridial filaments. × 650.

Fig. 50. Apical portions of two antheridial filaments of *N. gracilis* which are regularly and irregularly partitioned in alternate regions. Cells *a* and *b* contain large and small antherozoids. × 1000.

Fig. 51. A primary capitulum, *a*, of *C. delicatula* with three secondary capitula, *1*, *2* and *3*. Two of the secondary capitula bear no antheridial filaments and have merely grown out into long tubular cells. × 450.

PLATE 13

Fig. 52. A manubrium of *C. delicatula* with one primary capitulum which bears two secondary capitula, *1* and *2*. A small bud has developed on the primary capitulum near the point of attachment of one of the secondary capitula. × 650.

Figs. 53 and 54. Stages in the constriction of manubria of *C. delicatula*. × 800, 650.

Fig. 55. Portion of an antheridial filament of *C. delicatula* in which the anaphase groups of chromosomes lie in diagonally opposite corners of the cells. × 1800.

Fig. 56. Late anaphase stages in an antheridial filament of *N. flexilis* showing irregularities in distribution of chromosomes. The anaphase group numbered *1* is composed of but a single chromosome. × 1000.

Fig. 57. Slightly earlier anaphase stages than in the preceding figure. The anaphase group at the apex of the filament is composed of two chromosomes. × 1000.

Fig. 58. Late telophase stages in an antheridial filament of *N. flexilis* preceding cell plate formation. Large and small nuclei are present in the cells marked *a* and *b*. × 1000.

Fig. 59. A mature filament of *N. flexilis* with large and small nuclei in adjacent cells. × 1000.

Fig. 60. A globular manubrium of *L. alopercoides* which bore capitula at the two points marked *g*. × 350.

Fig. 61. A manubrium of *C. delicatula* with a small bud near the base. × 650.

Fig. 62. A primary capitulum, *a*, of *C. delicatula* with four secondary capitula, none of which bear antheridial filaments. × 700.

Fig. 63. A manubrium of *C. delicatula* with a large bud-like outgrowth near its apex. × 400.

Fig. 64. Final stage in the constriction of a manubrium of *C. delicatula*. × 600.

Fig. 65. A manubrium of *C. delicatula* which bore capitula at two points. × 500.

Fig. 66. A manubrium of *C. delicatula* with a bud, *b*, which is larger in size than the primary capitulum, *a*. × 500.

Figs. 67 and 68. Late telophase stages preceding cell plate formation in antheridial filaments of *N. flexilis*. The cells marked *a* each contain two large and one small nucleus. × 1000.

Fig. 69. Early anaphase stages in two terminal cells of an antheridial filament of *C. delicatula*, in which the chromosome groups are almost parallel and diagonal to the long axis of the filament. × 2200.

Fig. 70. Equatorial plate stage in the terminal cell of a filament of *C. delicatula*. The equatorial plate lies parallel to the long axis of the filament. × 1650.

Fig. 71. Early anaphase stages in two terminal cells of an antheridial filament of *N. flexilis* showing irregularities in distribution of chromosomes. × 1000.

Figs. 72 and 73. Mature filaments of *N. flexilis* with large and small nuclei. No nuclei are present in the cells marked *2* and *3*. × 1000.

Fig. 74. A secondary capitulum, *1*, of *N. flexilis* with two tertiary capitula, one of which, *2*, bears a quaternary capitulum, *3*. × 450.

PLATE 14

Fig. 75. A secondary capitulum of *C. coronata* f. maxima with four antheridial filaments and a bud-like outgrowth which has been divided into two cells. × 900.

Fig. 76. A secondary capitulum of *C. delicatula* which bears a single irregularly partitioned filament. The cells marked *a* are unusually large in comparison with the cells marked *b*. Large and small antherozoids are present in each of the cells, respectively. The regions indicated by *f* appear to be the outline of large original cells which were subsequently divided up into smaller cells. × 825.

Fig. 77. A similar irregularly partitioned antheridial filament of *C. delicatula* resembling a flat parenchyma of unequal cells. × 825.

Fig. 78. A conical outgrowth of cells on an antheridial filament of *C. delicatula*. The wall marked *2* is typically S-shaped. × 1100.

Fig. 79. A similar outgrowth on an antheridial filament of *C. delicatula* composed of unequal cells, *a* and *b*. × 1600.

Fig. 80. End of a filament of *C. delicatula* showing a cell fully six times as long as the other cells of the filament. × 825.

Fig. 81. A primary capitulum of *C. delicatula* with two secondary capitula, one of which has been divided up into eleven unequal cells. × 1100.

Fig. 82. Terminal portion of an antheridial filament of *C. delicatula* which has apparently been doubled back on itself. × 1000.

Fig. 83. A secondary capitulum of *C. delicatula* with three antheridial filaments, two of which, *a* and *b*, are unsegmented. × 800.

Fig. 84. A secondary capitulum of *C. delicatula* with two antheridial filaments one of which is short, thick, and irregularly partitioned into large and small cells. × 900.

Fig. 85. Division stages in an antheridial filament of *C. delicatula* showing the probable origin of irregularly partitioned filaments. × 900.

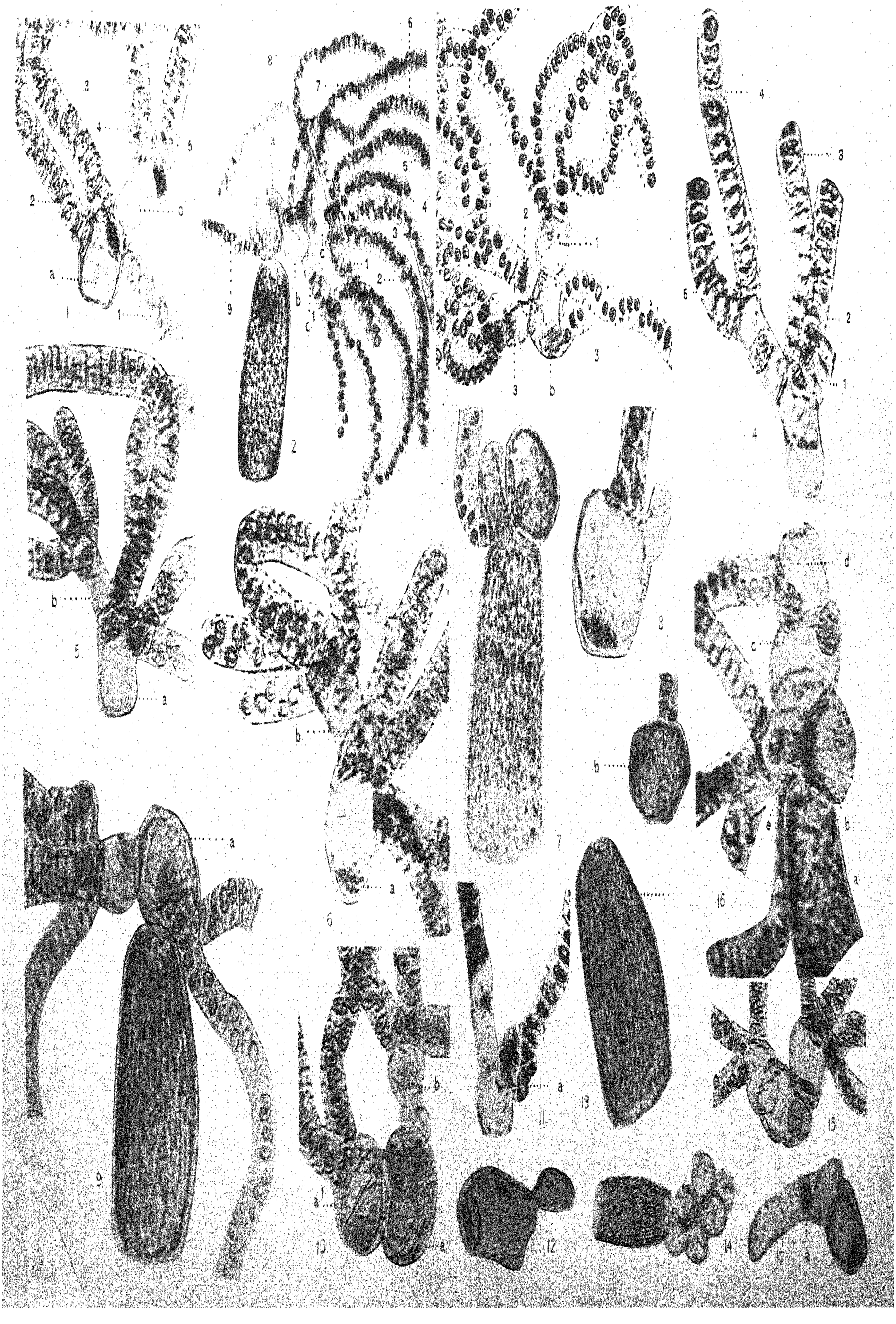
Fig. 86. Wedge-shaped nuclei in the cells of a curved portion of an antheridial filament of *C. delicutula*. × 825.

Figs. 87 and 88. Curved portions of antheridial filaments of *C. delicatula* in which the central cell has been divided by curved walls. × 825.

Fig. 89. A bent portion of an antheridial filament of *C. delicatula* showing the probable origin of branches. × 625.

Fig. 90. Anaphase stages in a bent portion of a filament of *C. delicatula* in which the anaphase groups of chromosomes lie parallel to the long axis of the filament and the short axis of the cell. × 825.

Fig. 91. A bent portion of a filament of *C. delicatula* which is irregularly divided up into cells. × 825.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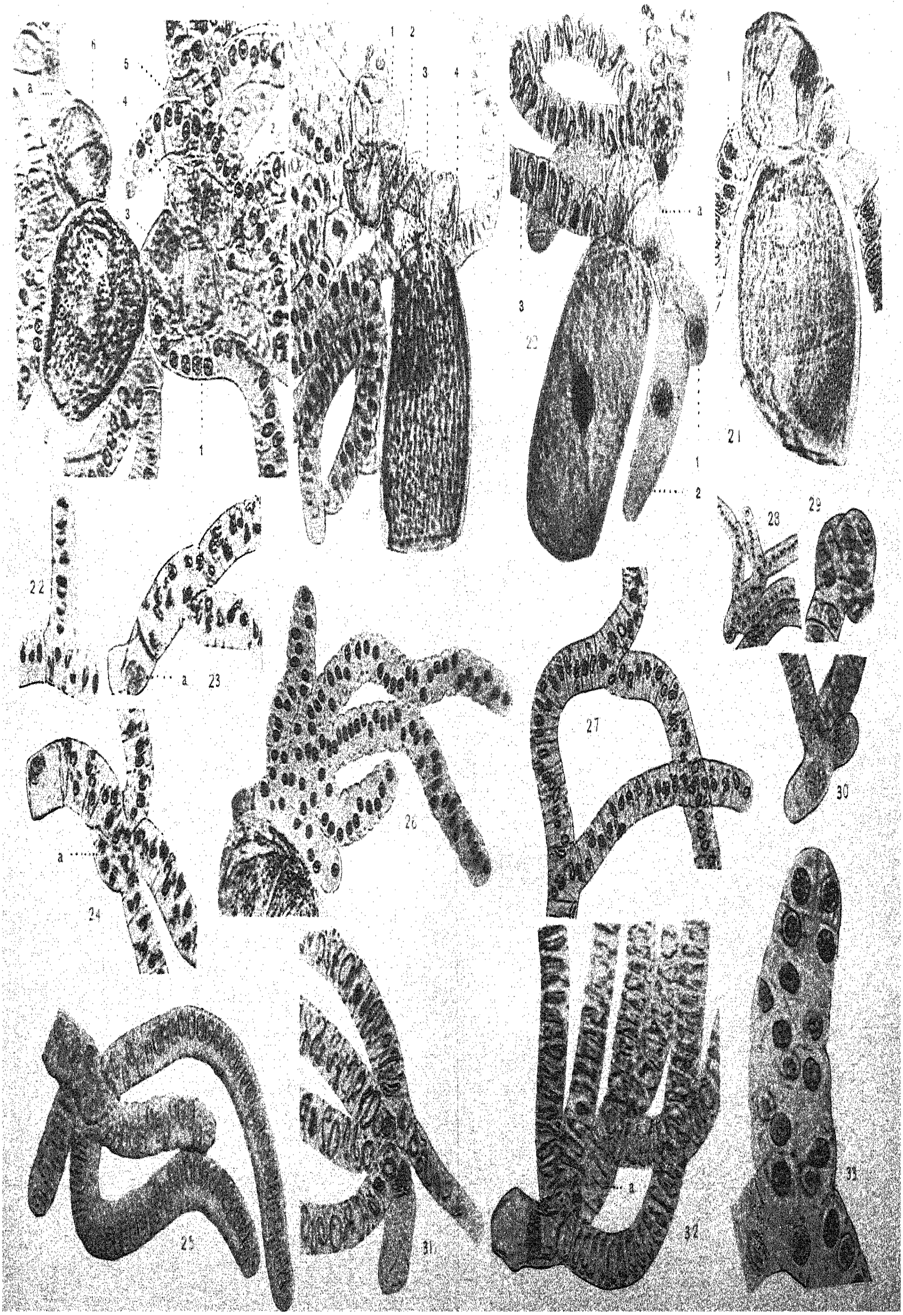
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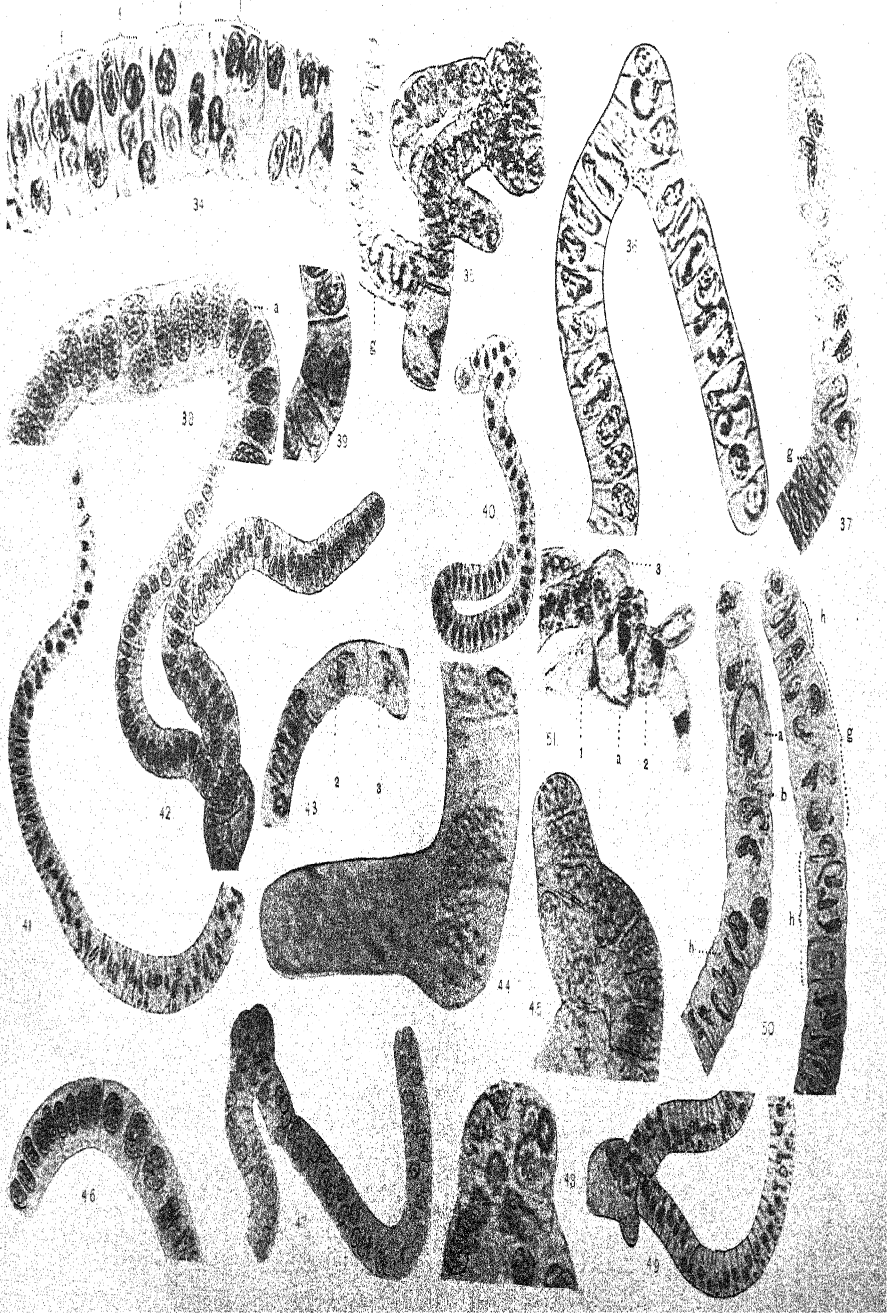
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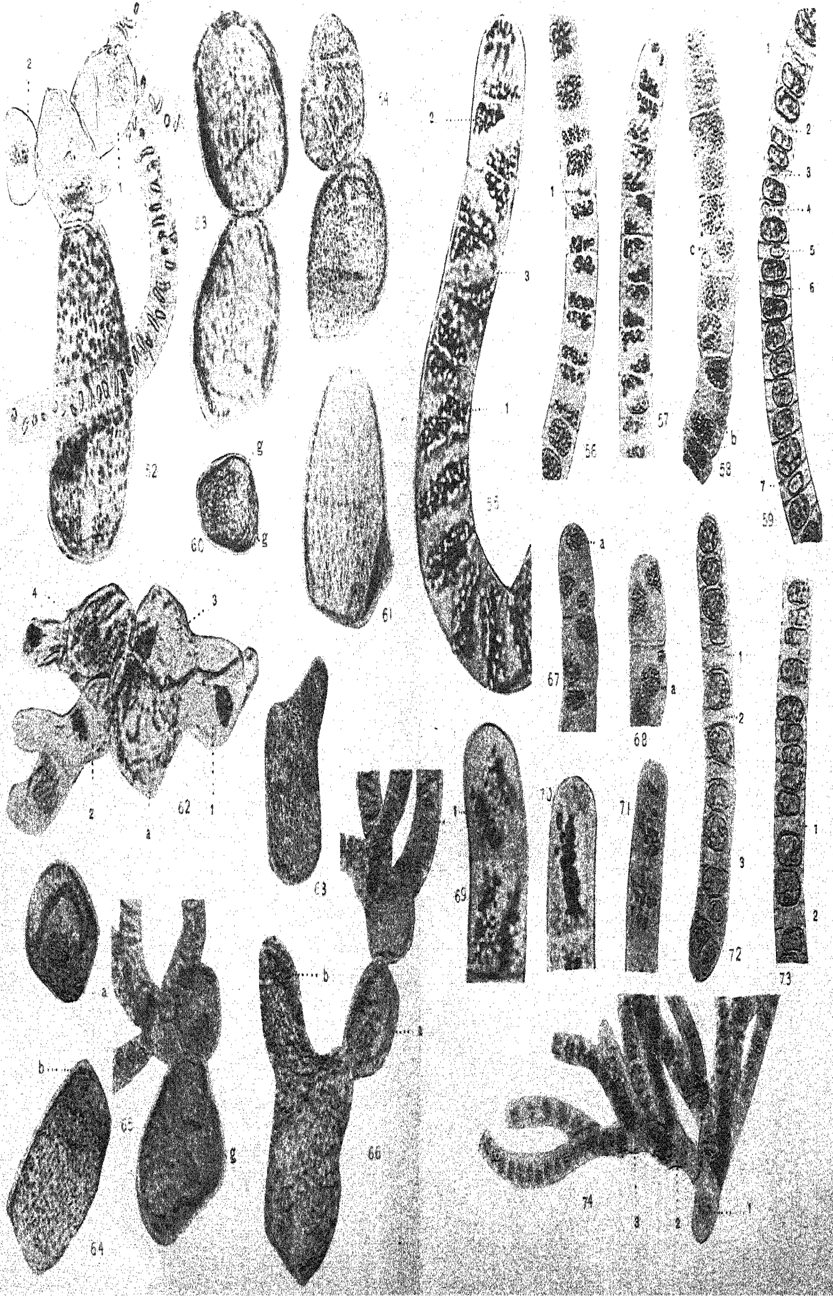
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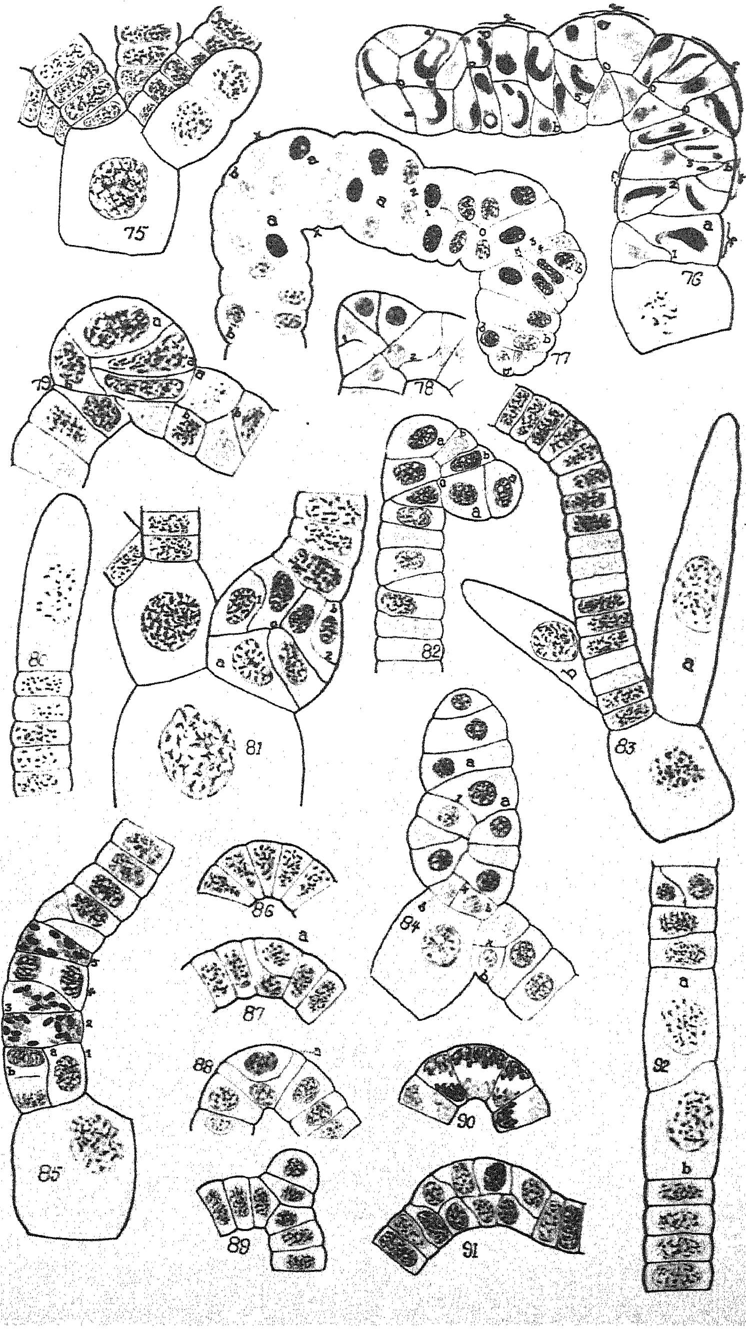

The glabrate species of Tilia

BENJAMIN FRANKLIN BUSH

It has long been apparent to me that there are two very distinct species of *Tilia* in Jackson County, Missouri. Mr. Kenneth Mackenzie, who lived in Kansas City some six or seven years, and with whom I was associated in the publication of the Manual of the Flora of Jackson County, Missouri, wrote to me after he moved to New York, some time early in 1903, that he had a specimen of a *Tilia* collected at Martin City, Jackson County, that differed from *T. Americana* (*T. glabra*) in having the summer shoot and the under surface of the leaves thereof tomentose. Mr. Mackenzie gave me minute directions regarding how to find the tree at Martin City, from which he collected specimens. I went there during the summer of 1903, located the tree beyond any doubt, and took flowering specimens from it; but there was no sign of the tomentose character that Mr. Mackenzie mentioned in his letter, the twigs, new shoots, bracts and flowers all being glabrous or nearly so. This naturally caused me to think that some error had been made, possibly by a misplaced label; or perhaps, through some mischance, Mr. Mackenzie had got hold of an aberrant branch, such as we sometimes see in *Crataegus;* and I dismissed the matter from my mind.

Two years after this I was collecting at Dodson, Missouri, but a few miles from Martin City, and I found a *Tilia* that certainly had the lower surface of the terminal leaves tomentose, or short hairy, but I was unable at the time to identify it with any other species than *T. Americana* (*T. glabra*), and I let it go without special effort to identify it.

During 1909 I saw this same form of *Tilia* at different places in the southern part of the County, and I observed it during several seasons until 1918, when Sargent published his two papers on the North American species of *Tilia*, but I could not identify my dubious *Tilia* with any species he described in these papers.

In September, 1921, Mr. Palmer and I were collecting in the southern part of the County just south of Greenwood, and he called my attention to a tree new to Jackson County, which was this same strange *Tilia* that I had been having so much trouble with since the summer of 1903.

Upon asking Mr. Palmer what species of *Tilia* it was, he told me that it was *T. floridana*, as so considered by Sargent in his revision of the species of *Tilia* in the Botanical Gazette in 1918. We took good specimens at the time, and the next June I collected specimens from the same tree in fine flower, and distributed these specimens to the principal herbaria in the country.

During the summer and autumn of 1924, while engaged in indentifying the native trees and shrubs in Swope Park for the Park Board, I was prompted to study this so-called *T. floridana*, with the interesting discovery that the glabrate species of *Tilia* are divisible into two groups: one, of which *T. glabra* is the type, having summer-shoots and the leaves thereon always the same; and the other with the leaves on the summer-shoots tomentose on the under surface and often on the upper (in some of the species the summer-shoots themselves are tomentose); to this latter group this so-called *T. floridana* belongs.

Desiring to ascertain just how far this dual life of some species of *Tilia* extends, I took up the study of the glabrate species, and have found that this character is present in the greater number of species of this group.

During the course of this study I consulted every book and paper containing anything about *Tilia* species that I could get, and I was somewhat astonished to find that the *T. floridana* of Sargent and the *T. floridana* of Small's Flora are two very different species.

I have here before me *Curtiss* 401,* the type-sheet of *T. floridana*, the type-specimens of *T. alabamensis*, and many specimens from Missouri, Arkansas, Oklahoma, and Texas labeled *T. floridana;* and a study of these specimens has convinced me that what Sargent has been calling *T. floridana* is really *T. alabamensis*.

Several of the forms which Sargent has placed under *T. floridana* as varieties,* I have concluded are worthy of specific rank, which I am therefore giving them here; and I am proposing one new species, which seems by a number of good characters to be distinct enough to warrant recognition.

Through the kindness of Prof. Wm. Trelease I have been able to examine all the *Tilia* material in the University of Illinois Herbarium. To Mr. Chas. C. Deam of Indiana, who placed at my disposal all the material of this genus in his collection, and to Dr. P. C. Standley, of the United States National Museum, who kindly supplied me with certain *Tilia* species which I desired, I am indebted, and I wish herein to acknowledge their assistance. To Mr. W. W. Ashe, of Washington, D. C., I am grateful for many suggestions, many notes on the character of the species, and the loan of all of his type material and numerous specimens of *Tilia;* and it was through our collaboration that the peculiar character of the summer-shoots was discovered.

To Prof. C. S. Sargent, pioneer in this field of study, who has labored for many years to distinguish the species of *Tilia*, I am under obligation for the loan of critical material, and the free use of his published papers on the species of the genus.

Having examined some five or six hundred specimens of *Tilia* in the course of this investigation, I feel quite confident of the conclusions that I have come to and for the glabrate species I present the following:

Key to glabrate species of Tilia

Leaves creno-serrate; summer-shoots tomentose........... 5. TILIA CRENO-SERRATA
  Leaves glabrous as unfold or nearly so, soon glabrous, or in a variety of *T. glabra* permanently minutely short-pubescent beneath.
    Flowers less than 8 mm. long; corymbs small; summer-shoots tomentose; terminal leaves on shoots not cordate at the base.................. 6. TILIA ASHEI
    Flowers 8–12 mm. long; corymbs mostly many-flowered; terminal leaves on shoots usually cordate.
      Pedicels usually glabrous, or minutely scabrous; summer-shoots glabrous; corymbs mostly gla-

brous, many-flowered.

- Leaves glabrous beneath............ 1. TILIA GLABRA
- Leaves permanently short-pubescent beneath............ 1A. TILIA GLABRA NEGLECTA

Pedicels usually tomentose or scabrous; summer-shoots tomentose or scabrous.

- Bracts narrow.
  - Leaves green or yellow-green on the lower surface.... 2. TILIA LEUCOCARPA
  - Leaves glaucous or glaucescent on the lower surface.... 2A. TILIA LEUCOCARPA GLAUCESCENS
- Bracts very broad, much longer than the peduncle; leaves glaucescent beneath. 2B. TILIA LEUCOCARPA BREVIPEDUNCULATA

Leaves loosely tomentose as unfold, glabrate by flowering time.

- Pedicels glabrate by flowering time; leaves deep bronze-colored as unfold; summer-shoots glabrous. 7. TILIA AUSTRALIS
- Pedicels permanently tomentose or scabrous.

Leaves nearly orbicular; twigs stout, red; flowers 10–12 mm. long.

- Leaves mostly cordate at the base; primary veins of usually 9 or 10 pairs; summer-shoots pubescent......... 3. TILIA VENULOSA
- Leaves mostly obliquely truncate at the base, not cordate; primary veins of 12 or 13 pairs.............. 3A. TILIA VENULOSA MULTINERVIS

Leaves ovate or longer; twigs rarely red (sometimes red in *Cocksii*).

- Leaves often densely glaucous beneath; upland species... 8. TILIA HYPOLEUCA

- Leaves green, pale or glaucescent beneath.
  - Terminal leaves on shoots never cuneate at the base.
    - Leaves blue-green; twigs red or brown; summer-shoots tomentose; lowland species......... 9. TILIA COCKSII
    - Leaves light green; twigs tan.
      - Summer-shoots tomentose; leaves mostly small, broadly ovate, mostly cordate..... 10. TILIA FLORIDANA
      - Summer-shoots glabrous; leaves larger.
        - Leaves mostly round-ovate, mostly cordate at the base........ 11. TILIA ALABAMENSIS
        - Leaves ovate-oblong, mostly oblique at the base.. 11A. TILIA ALABAMENSIS OBLONGIFOLIA
  - Terminal leaves on shoots usually cuneate at the base, of an ovate type.
    - Leaves larger, 8–10 cm. long, pale beneath.... 4. TILIA LITTORALIS
    - Leaves smaller, 7–8 cm. long, glaucous beneath............... 4A. TILIA LITTORALIS DISCOLOR

1. TILIA GLABRA Vent., An. Hist. Nat. **2**: 62. 1800.—*T. Americana* Am. Aucts., but probably not L. 1753, or at least in very small part.—This species, the type of the group, has the widest distribution of any species of the genus in North America, ranging from New Brunswick south to Eastern Kentucky, west to west-central Missouri, eastern and northeastern Kansas, north to Lake Superior and Saskatchewan; apparently a highland species.[1]

Sargent states that *T. glabra* has "lower surface of leaves light green and lustrous, with conspicuous tufts of axillary hairs; rays of the corymbs and pedicels glabrous, or in some specimens decidedly pubescent or scabrous; flowers opening early in July, 12.5 mm. long, glaucous; fruit 8–12.5 mm. long, short-oblong, or oblong-ovoid."

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[1] That this study may be of greater benefit to collectors, I have cited a great many specimens, that everyone may know just what my opinions are in regard to these species.

CANADA: Quebec, *Victorin* 16311, August 28, 1922, D. Herb;[2] Wakefield, *Victorin* 10183, September 11, 1920, D. Herb.—NEW JERSEY: Cranberry Lake, *Mackenzie* 2189, July 15, 1906, D. Herb.—PENNSYLVANIA: Warren, *Ashe*, August 1, 1924, A. Herb.—MARYLAND: Alberton, *Holm*, June 1, 1913, U. of Ill. Herb.—DISTRICT OF COLUMBIA: Washington, *Ashe*, October 17, 1925, cultivated tree on Carnegie Library Square, A. Herb.—INDIANA: Bluffton, *Deam* 1200, July 17, 1906, U. of Ill. Herb.; Bluffton, *Deam* 14520, August 16, 1914, D. Herb.; Bristol, *Deam* 31360, July 7, 1920, D. Herb.; Connelton, *Deam* 16597, June 29, 1915, D. Herb.; Chesterton, *Deam* 18008, August 22, 1915, D. Herb.; Crawleyville, *Deam* 29168, August 17, 1919, D. Herb.; Cherubusco, *Deam* 14352, June 24, 1915, D. Herb.; Carmel, *Deam* 8695, June 17, 1911, D. Herb.; Crawfordsville, *Deam* 17617, July 20, 1915, D. Herb.; Carmel, *Deam* 8688, June 17, 1911, D. Herb.; Camby, *Deam* 11455, July 4, 1912, D. Herb.; Chesterfield, *Deam* 8152, May 14, 1911, D. Herb.; Gomiskey, *Deam* 28046, July 13, 1919, D. Herb.; Delphi, *Deam* 17762, July 22, 1915, D. Herb.; Dune Park, *Chase* 476, June 16, 1897, U. of Ill. Herb.; Denver, *Deam* 36796, June 30, 1922, D. Herb.; East Mount Carmel, *Deam* 25470, June 18, 1918, D. Herb.; Fairmount, *Deam* 14491, 32051, August 5, 1920, D. Herb.; Fort Wayne, *Deam* 14491, August 2, 1914, D. Herb.; Frankfort, *Deam* 17640, July 21, 1915, D. Herb.; Franklin, *Deam* 11868, June 8, 1912, D. Herb.; Gibson County, *Schneck*, June 28, 1890, D. Herb.; Griffin, *Deam* 8344, May 24, 1911, D. Herb.; Greencastle, *Deam* 17567, July 8, 1915, D. Herb.; Georgetown, *Deam* 32113, August 21, 1920, D. Herb.; Hancock County, *Deam* 8876, June 24, 1911, D. Herb.; Hartville, *Deam* 36905, July 20, 1922, D. Herb.; Hillsdale, *Deam* 11923, August 4, 1912, D. Herb.; Howe, *Deam* 14981, August 29, 1914, D. Herb.; Howe, *Deam* 36557, June 22, 1922, D. Herb.; Hudson Lake, *Deam* 8759, June 17, 1911, D. Herb.; Indianapolis, *Deam* 8589, June 6, 1911, D. Herb.; Kentland, *Deam* 21531, August 30, 1916, D. Herb.; Lafayette, *Deam* 17697, July 20, 1915, D. Herb. Lafayette, *Dorner*, June 14, 1902, D. Herb.; Leesburg, *Deam* 34466, July 3, 1921, D. Herb.; Leavenworth, *Deam* 16477, June 26, 1915, D. Herb.; Linngrove, *Deam* 31971, July 25, 1920, D. Herb.; Logans Port, *Deam* 17834, July 22, 1915, D. Herb.; Montpelier, *Deam* 32062, August 5, 1920, D. Herb.; New Albany, *Deam* 9373, July 31, 1911, D. Herb.; Newburg, *Deam* 16687, July 2, 1915, D. Herb.; Newburg, *Deam* 16689, July 2, 1915, D. Herb.; Newburg, *Deam* 16714, July 2, 1915, D. Herb.; New Harmony, *Deam* 16799, July 4, 1915, D. Herb.; New Harmony, *Deam* 16826, July 4, 1915, D. Herb.; Parke County, *Deam* 9910, September 3, 1911 D.

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[2] D. Herb., U. of Ill. Herb., A. Herb., and U. S. N. Herb., and A. A. Herb. denote the Deam Herbarium, University of Illinois Herbarium, Ashe Herbarium, the United States National Museum Herbarium and Arnold Arboretum Herbarium, respectively.

Herb.; Pekin, *Deam* 18990, September 12, 1915, D. Herb.; Peru, *Deam* 17904, July 24, 1915, D. Herb.; Plymouth, *Deam* 29661, September 11, 1919, D. Herb.; Peru, *Deam* 17899, July 24, 1915, D. Herb.; Parke County, *Deam* 9910, September 3, 1911, D. Herb.; Pine Village, *Deam* 9694, August 16, 1911, D. Herb.; Porter County, *Deam* 8824, June 17, 1911, D. Herb.; Patoka, *Deam* 16871, July 6, 1915, D. Herb.; Patoka, *Deam* 16873, July 6, 1915, D. Herb.; Patoka, *Deam* 16909, July 6, 1915, D. Herb.; Patoka, *Deam* 16915, July 6, 1915, D. Herb.; Raccoon, *Deam* 17572, July 8, 1915, D. Herb.; Rome City, *Deam*, July 21, 1904, D. Herb.; Romona, *Deam* 8958, June 25, 1911, D. Herb.; Riverdale, *Deam* 17300, July 13, 1915, D. Herb.; Redkey, *Deam* 15430, September 13, 1914, D. Herb.; Redkey, *Deam* 15431, September 13, 1914, D. Herb.; Saint Paul, *Deam* 9213, July 15, 1911, D. Herb.; Shawnee Ridge, *Deam* 18191, August 25, 1915, D. Herb.; Shelbyville, *Deam* 20607, June 30, 1916, D. Herb.; Southbend, *Deam* 31414, July 8, 1920, D. Herb.; Starke County, *Deam* 9651, August 15, 1911, D. Herb.; Shoals, *Deam* 11396, June 30, 1912, D. Herb.; Shoals, *Deam* 17133, July 10, 1915. D. Herb.; Springville, *Deam* 31462, July 9, 1920, D. Herb.; Salem, *Deam* 17420, July 15, 1915, D. Herb.; Spencer, *Deam* 17514, July 17, 1915, D. Herb.; Spencer, *Deam* 17525, July 17, 1915, D. Herb.; Spencer, *Deam* 17539, July 18, 1915, D. Herb.; Steuben County, *Deam* 9274, September 20, D. Herb.; The Shades, *Deam* 9274, July 23, 1911, D. Herb.; The Shades, *Deam* 17584, July 19, 1915, D. Herb.; The Shades, *Deam* 17587, July 19, 1915, D. Herb.; Tioga, *Deam* 8880, June 25, 1911, D. Herb.; Topeka, *Deam* 31285, June 6, 1920, D. Herb.; Vernon, *Deam* 11298, June 23, 1912, D. Herb.; Versailles, *Deam* 16128, June 18, 1915, D. Herb.; Versailles, *Deam* 16128, June 18, 1915, D. Herb.; Versailles, *Deam*, June 18, 1915, D. Herb.; Versailles, *Deam* 16131, June 18, 1915, D. Herb.; Wabash, *Deam* 17909, July 24, 1915, D. Herb.; Wells County, *Deam* August 27, 1889, D. Herb.; West Baden, *Deam* 17363, July 14, 1915, D. Herb.; Winamac, *Deam* 32202, August 22, 1920, D. Herb.—ILLINOIS. Algonquin, *Nason*, July 14, 1878, U. of Ill. Herb.; Canton, *Wolf*, date not given, U. of Ill. Herb.; Camp Grant, *E. W. M.*, June 15, 1919, U. of Ill. Herb.; Carlinville, *Andrews*, June 30, 1890, U. of Ill. Herb.; Carlinville, *Andrews*, June 30, 1890, U. of Ill. Herb.; Coffee Mill, *E. W. M.*, September 17, 1919, U. of Ill. Herb.; Desplaines Valley, *Chase*, June 24, 1895, U. of Ill. Herb.; Elgin, *Sherff* 1941, September 14, 1912, U. of Ill. Herb.; Grayville, *E. W. M.*, September 14, 1919, U. of Ill. Herb.; Hanging Rock, *Schneck* May 15, 1898, U. of Ill. Herb.; Jasper County, *Ridgway* 1585, October 24, 1921, R. Herb.; Maywood, *Chase*, June 24, 1896, U. of Ill. Herb.; Mount Carmel, *Schneck*, June 1, 1901, U. of Ill. Herb.; Mud River, *Chase*, July 5, 1900, U. of Ill. Herb.; Peoria, *McDonald*, June 1884, U. of Ill. Herb.; Richland County, *Ridgway* 544, July 19, 1921, R. Herb.; Richland County, *Ridgway* 547, July 19, 1921, R. Herb.; Richland County, *Ridgway*, July 19, 1921, R. Herb.; Richland County, *Ridgway*, 1500, October 1, 1921, R. Herb.; Richland County, *Ridgway*, 1501, October 1, 1921, R. Herb.; Richland County, *Ridgway*, 1501, October 1, 1921, R. Herb.; Richland County, *Ridgway*, 1556, October 12, 1921, R. Herb.; Richland County, *Ridgway*, 1556, October 12, 1921, R. Herb.; Richland County, *Ridgway*, 2169, August 12, 1924, R. Herb.; Richland County, *Ridgway*, 2169, August 12, 1924, R. Herb.; Richland County, *Ridgway*, 2170, August 12, 1924,

R. Herb.; Riverside, *Lansing* 1445, July 22, 1902, U. of Ill. Herb.; Taylorville, *De Motte*, June 13, 1896, U. of Ill. Herb.; Thornton, *Lansing*, 1396, July 14, 1902, U. of Ill. Herb.; Urbana, *G. G.*, October 14, 1898, U. of Ill. Herb.; Urbana, *G. P. C.*, Winter, 1898, U. of Ill. Herb.; Urbana, *Waite*, June 21, 1886, U. of Ill. Herb.; Urbana, *E. W. M.* 38, September 28, 1919, U. of Ill. Herb.; Wady Petra, *Chase* 661, July 5, 1900, U. of Ill. Herb.; Wady Petra, *Chase* 862, Seprember 28, 1900, U. of Ill. Herb.; Wady Petra, *Chase*, September 28, 1900, U. of Ill. Herb.; Wady Petra, *Chase* 661, July 5, 1900, U. of Ill. Herb.; Williamsville, Chase 1854, July 5, 1908, U. of Ill. Herb.—MISSOURI: Allenton, *Kellogg*, July 2, 1910, A. A. Herb.; Atherton, *Mackenzie* 91, August 1, 1902, D. Herb.; Campbell, *Bush* 9293, October 17, 1920, U. of Ill. Herb.; Courtney, *Bush* 9697A, September 30, 1921, U. of Ill. Herb.; Courtney, *Bush* 9697B, September 30, 1921, U. of Ill. Herb.; Courtney, *Bush* 7140, June 15, 1914, U. of Ill. Herb.; Dumas, *Bush* 10129, July 27, 1923, U. of Ill. Herb.; Dumas, *Bush* 10129A, July 27, 1923, U. of Ill. Herb.; Ilasco, *Davis* 2164, September 30, 1914, A. A. Herb.; Webster Grove, *C. F.*, June 29, 1917, U. of Ull. Herb.—MICHIGAN: Burt Lake, *Deam* 28831, July 24, 1919, D. Herb.; Granger, *Fuller*, month not given, 1911, U. of Ill. Herb.; Glen Haven, *Cowles*, August 19, 1906, U. of Ill. Herb.; Lansing *Yuncker*, 531, August 12, 1917, U. of Ill. Herb.—MINNESOTA: Dent, *Bergman* 2851, July 10, 1913, D. Herb.; Perham, *Chandonnet*, July 14, 1910, D. Herb.[3]

1A. TILIA GLABRA NEGLECTA (Spach) n. var.—*T. neglecta* Spach, Ann. Sci. Nat. II. **2:** 140. 1834.—I have not been able to see many specimens of this form, but those cited below appear to me to represent this species or variety, which, after all, may be merely a form of *T. glabra*. Ashe[4] lays great stress on the straight, simple, firmly attached pubescence on the lower surface of the leaves; but I have seen specimens of *T. glabra* from Indiana Illinois, Missouri, Michigan, and Minnesota that had this character well developed, but they were true *T. glabra*, and Mr. Deam bears me out in this statement.

CONNECTICUT: Guilford, *Trelease*, August 1921, U. of Ill. Herb.; Stony Creek, *Trelease*, July, 1921, U. of Ill. Herb.; Stony Creek, *Trelease*, July, 1921 U. of Ill. Herb.; Stony Creek, *Trelease*, July 29, 1921, U. of Ill. Herb.

2. TILIS LEUCOCARPA Ashe, Bull. Charleston S. Car. Mus. **14:** 32. October 24, 1918.—*T. nuda* Sargent, Bot. Gaz. **66:** 425. November, 1918.—Alabama to Texas and extreme southeastern Arkansas, apparently a lowland species.

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[3] I have examined three specimens collected by Miss Mulford at Santa Fe, New Mexico, labeled *Tilia*. These specimens are certainly *T. glabra*, and judging by the labels were collected from wild trees; but it seems so very improbable that *T. glabra* should be found in New Mexico that I have refrained from citing these specimens as collected in the known range of this species.

[4] Bot. Gaz. **53:** 32. 1926.

Mr. Ashe wrote me that the type-specimen of *T. leucocarpa* has a tomentose summer-shoot. He did not mention this in his descripion of this species, since he thought the specimen was aberrant in this respect.

Sargent says of *T. nuda*, "buds ovoid, obtusely pointed, dull red, glabrous, 4–5 mm. long; flowers opening early in June, 8 mm. long, on densely hoary-tomentose pedicels, in broad glabrous cymes; fruit ripening in September, subglobose to depressed-globose, covered with rusty tomentum, 6–8 mm. in diameter; leaves usually without tufts of axillary hairs, the lower surface not lustrous."

In the specimens examined by me, I have found that the leaves are never lustrous, and that the inside of the sepals are glabrous, the only species of the genus having this character.

TEXAS: Livingston, *Ashe* 41, September 22, 1923, A. Herb.—MISSISSIPPI: Natchez, *Miss Compton*, April 10, 1925, A. Herb.; this specimen and the next cited from type-tree of *T. nuda;* Natchez, *Miss Compton*, April 10, 1925.—ALABAMA: Demopolis, *Ashe* 42, June 2, 1925, A. Herb.; Demopolis, *Ashe* 43, June 2, 1925, A. Herb.; Greensboro, *Ashe* 41, April 28, 1925, A. Herb.; Greensboro, *Ashe* 41, June 2, 1925, A. Herb.; Greensboro, *Ashe* 42, June 2, 1925, A. Herb.; Greensboro, *Ashe* 42, April 26, 1925, A. Herb.; Greensboro, *Ashe* 42, June 2, 1925, A. Herb.; Greensboro, *Ashe* 41, April 18, 1925, A. Herb.; Greensboro, *Ashe* 41, June 2, 1925, A. Herb.; Greensboro, *Ashe* 42, April 28, 1925, A. Herb.; Greensboro, *Ashe* 42, July, 1925, A. Herb.; Greensboro, *Ashe* 42, June 2, 1925, A. Herb.; Greensboro, *Ashe* 3, September 30, 1918, A. Herb.; Greensboro, *Ashe* 3, September 30, 1918, A. Herb.; Greensboro, *Ashe* 3, May, 1909, A. Herb.; all these numbered 3 are the type-sheets of *T. leucocarpa;* Selma to Marion, along the road, *Ashe* 40, June 2, 1925, A. Herb.; Greensboro, *Ashe* 42, July 28, 1925.

2A. TILIA LEUCOCARPA GLAUCESCENS (Sargent) N. C.—*T. nuda glaucescens* Sargent, Bot. Gaz. **66:** 427. 1918.—Alabama to Louisiana and Texas, apparently a lowland or coastal species.

Summer-shoots tomentose or pubescent; leaves glaucous beneath. I have not been able to see many specimens of this form and cannot be sure whether it is distinct from the specific form, as the glaucous under-surface of the leaves would indicate, or whether it is merely a form not worthy of recognition.[5]

ALABAMA: Lawley, *Harper*, June 11, 1924, U. of Ill. Herb.

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[5] Ashe has recently pointed out that this species frequently occurs in a form that has the leaves attenuate-acuminate. This may be known as TILIA LEUCOCARPA forma ATTENUATA Ashe, collected at Greensboro, Alabama, *Ashe* 41, June 2, 1925.

2B. TILIA LEUCOCARPA BREVIPEDUNCULATA (Sargent) Ashe, N. C.—*T. nuda brevipedunculata* Sargent, Bot. Gaz. 66: 427. 1918.—Alabama and Mississippi to extreme southwestern Arkansas, Louisiana and Texas.

Doubtless a good distinct species, but in deference to Mr. Ashe's wishes, I am merely transfering this form to *T. leucocarpa*. Summer shoots tomentose or pubescent; bracts very broad, (narrow in *leucocarpa*).

Sargent says of this form, "leaves ovate, finely crenate-serrate with gland-tipped teeth; dark red-brown branchlets, slender, glabrous."

OKLAHOMA: McCutcheon County, *Ashe* 68, August 28, 1921, A. Herb.—TEXAS: Woods County, *Ashe* 37, September 16–17, 1921, A. Herb.

3. TILIA VENULOSA Sargent, Bot. Gaz. 66: 428. 1918.—North Carolina, apparently a mountainous species. Summer-shoots pubescent with long subappressed hairs; leaves with beautifully anastomosing veins.

Sargent says of this species, "leaves hoary-tomentose when they unfold, the veinlets conspicuous; branchlets stout, bright red; flowers opening early in July, 8 mm. long, on slightly pubescent pedicels; fruit ripening at the end of September, subglobose, 6–8 mm. in diameter, covered with loose light-brown pubescence."

NORTH CAROLINA: Hickory Nut Gap, *Ashe* 7A, May 28, 1916, TYPE, A. Herb.; Catawba, *Bilt. Herb*, May 18, 1904, U. S. N. Herb. 960281, labeled "Tilia," "A species to be described by Mr. Ashe." Penciled *T. eburnea* by someone just below the label, but this sheet is really *T. venulosa*, and one of the *glabra* group, while *eburnea* is the same or nearly the same as *T. lasioclada* Sargent. When Mr. Ashe described *T. eburnea* in 1902, he mentioned in the description another species of *Tilia* growing with *T. eburnea*, which perhaps was what caused Mr. Beadle to write as above; Old Fort to Swananoa Gap along the road, *Ashe*, October, 1916, A. Herb.; Round Knob, *Ashe* April 25, 1925, A. Herb.; Round Knob, *Ashe*, May 1, 1925, A. Herb.; Round Knob, *Ashe*, July 25, 1925, A. Herb.; Round Knob, *Ashe*, October 14, 1925, A. Herb.; Swananoa Gap, *Ashe*, April 25, 1916, A. Herb.; Swananoa Gap, *Ashe*, April 25, 1916, A. Herb.

3 A. TILIA VENULOSA MULTINERVIS Sargent, Bot. Gaz. 66: 428. 1918.—North Carolina, only a single tree known. I have not been able to see any specimen of this form, which, so far as known, consists of a single tree near Saluda, North Carolina. It may belong to *T. venulosa*, or it may be entirely distinct; only

further observations can decide this, and for the present it may remain where Sargent placed it.

4. TILIA LITTORALIS Sargent, Bot. Gaz. **66**: 428. 1918.—Georgia, and perhaps elsewhere along the coast, as it appears to be a lowland or coastal form. The glabrous summer-shoots, small, glabrous, unsymmetrical leaves, and conspicuous tufts of axillary hairs and densely pubescent pedicels seem to mark this as a distinct species. Sargent says of this, "fruit ellipsoid to depressed-globose, apiculate, covered with pale brown tomentum; flowers 8 mm. long; leaves hoary-tomentose when they unfold."

4A. TILIA LITTORALIS DISCOLOR Sargent, Bot. Gaz. **66**: 430. 1918.—A single tree is known, on Colonel's Island Georgia, growing with the typical form. As there is no further evidence that this is a distinct form, it may well be only an individual variation of the species, such as are often seen of other species in the field; but until further observations and collections are made, it may be retained where placed by Sargent.

It is assumed that this form has, like the species, glabrous summer-shoots, and is a lowland or coastal form.

5. TILIA CRENOSERRATA Sargent, Bot. Gaz. **66**: 430. 1918.—*T. floridana* Sargent, Man. 672, in part, 1903, not *T. floridana* Small, 1903.—Georgia and Florida, and perhaps elsewhere along the coast, as it appears to be a lowland or coastal species.

The small, ovate or round-ovate, crenate or crenate-serrate leaves mark this so distinctly that it cannot be confused with any other species. Sargent says of this, "slender, glabrous, red-brown branchlets"—which may refer to the early branchlets, for the summer-shoots of this species are tomentose or pubescent.

FLORIDA: Salt Spring, *Ashe*, April 14, 1923, A. Herb.; Salt Spring, *Ashe*, June 10, 1925, A. Herb.; Gainesville, *Ashe* 27, June 9, 1925.

6. **Tilia Ashei** sp. nov. Leaves ovate or at tips of vigorous shoots oblong-ovate, or slightly obovate, 6 to 9 cm. long, 4.5 to 6.5 cm. wide, abruptly short-acuminate at apex, oblique at the truncate base, or at the base of shoots or on weak shoots obliquely cordate at base, sharply serrate with small glandular often incurved teeth, or on weak shoots finely serrate with straight teeth, when they unfold bronze-colored, the edges permanently ciliate, glabrous on the upper surface except for a few simple straight appressed hairs, some of which are often persistent and make the upper surface scabrate, glabrous on the lower surface except for occasional small tufts of fascicled pubescence along the midrib

and veins as they unfold which are early deciduous, or with a few long appressed simple hairs on midrib or petiole; when the flowers open thick and firm, dark green and lucid above, glabrous or scabrous near the edges, much paler, and dull glaucescent beneath occasionally with minute axillary tufts, and a few simple straight appressed hairs on midrib otherwise glabrous except for the margins which are permanently ciliate; petioles glabrous, or rarely with a few simple straight appressed hairs, seldom more than 2 cm. long, usually bent at a sharp angle near the middle; leaves on summer shoots larger and thicker, cuneate or rounded at base, with small distant glandular spiculate teeth, as they unfold pubescent above with straight appressed hairs mixed along the veins with fascicled hairs, the lower surface, as well as petioles and summer shoots tawny or grayish tomentose, at length loosely pubescent; stipules broadly lanceolate, acuminate, silky canescent on both sides. Twigs slender, seldom 3 mm. thick, glabrous as they appear, dark brown or purplish the first winter; buds ovate, obtuse, small, glabrous, dark red-brown or purplish. Flowers 6 to 7 mm. long on slender loosely pubescent pedicels in compact 9 to 18-flowered pubescent corymbs, peduncle slender sparingly stellate pubescent for at least a few days; sepals ovate-lanceolate, acuminate, 5 mm. long, gray pubescent without, silky canescent at base within; staminodea as long as the sepals; petals broadly lanceolate about 1.5 mm. wide and about 5 mm. long; style 5 mm. long, villose at base; fruit about 7 mm. thick, is subglobose and covered with short grayish tomentum; bract usually longer than the corymbs is oblong 5 to 9 cm. long, 1.5 to 2.5 cm. wide, mostly rounded at both ends, somewhat uneven at base, nearly sessile, glabrous on both faces except for scattered pubescence along the peduncle before the flowers open.

A small tree, 5 to 10 m. high, growing with *Tilia floridana* Small, *T. porracea* Ashe, *Acer barbatum* Mx., and *Quercus laurifolia* Mx. on slopes along streams and particularly at stream heads in western Florida. The flowers appear about the middle of June, somewhat later than those of *T. floridana*, and the fruit ripens in September. Hickory Head, Okaloosa County, W. W. Ashe, April 25, June 20, 1923, and November 7, 1924, from the same tree (No. 3, type). Shore of Choctawhatchee Bay near Pippin Point, Walton County, W. W. Ashe, April 25, May 27, October 25, 1923 (No. 1, P. P.). Turkey Head, Okaloosa County, W. W. Ashe, April 25, 1923, June 13, 1925 (No. 47)

TILIA ASHEI resembles *T. floridana* in size and habit and in size and shape of its leaves, and in having, like that species in its typical form, pubescent summer shoots. It differs from *T. floridana* in having leaves bronze colored and essentially glabrous as they unfold, as a rule devoid of axillary tufts, thick, dark green and when mature lucid on the upper surface, in its somewhat later time of flowering and in its smaller and more compact corymbs.

The proposed species resembles *T. leucocarpa* Ashe in having glabrous foliage, bronze as it unfolds, and in its small compact corymbs and pubescent summer shoots; but is separated from all forms of that species by having smaller flowers, dark green lucid leaves of narrower outline and by having the leaves on the summer shoots ovate and prevailingly narrowed at base in place of deltoid and truncate or cordate.

Mr. Ashe originally referred this tree to *T. floridana*, and later to *T. Cocksii*. It differs from *T. floridana* in having (1) deep bronze-red leaves as they unfold (the leaves are green in *T. floridana*); (2) leaves practically glabrous (except strongly ciliate) before full grown (in *T. floridana* pubescent always until grown); (3) bracts glabrous from the start (more or less tomentose until flowering time in *T. floridana*); (4) flowers mostly in small corymbs (corymbs generally large in *T. floridana*); (5) flowers always compact (in *T. floridana* always wide-spreading even if corymbs are very small); (6) leaves on summer shoots ovate, narrowed at base (in *T. floridana* leaves on summer shoots broadly ovate, truncate, or broadly cordate at base); (7) leaves on summer-shoots crenate-serrate (*T. floridana* leaves on summer shoots are serrate with sharp incurved teeth); (8) leaves dark lucid green (*T. floridana* leaves are bright green).

From *T. Cocksii* it differs in having (1) leaves and bracts smooth beneath as they are unfolding (in *T. Cocksii* the leaves and bracts are tomentose as they are unfolding); (2) leaves dull and glaucescent below (in *T. Cocksii* blue-green and lustrous belew); (3) fruit ripening in September (*T. Cocksii* ripens its fruit in July); (7) buds small and obtuse (acute in *Cocksii*).

From *T. leucocarpa* this species differs in having (1) flowers 6–7 mm. long (8–10 mm. long in *T. leucocarpa*); (2) flowers in smaller, more compact corymbs (widely spreading in *T. leucocarpa*); (3) narrower leaves, dark green and lucid above and pale (not yellowish-green) beneath (yellowish-green beneath in *T. leucocarpa*); (4) leaves on summer shoots oval or prevailingly narrowed at the base (in *T. leucocarpa* the leaves on summer shoots are deltoid or broadly ovate or cordate, or truncate at the base).

FLORIDA: Hickory Head, *Ashe* 3, April 23, 1923, A. Herb.; Hickory Head, *Ashe* 3, April 23, 1923, A. Herb.; Hickory Head, *Ashe* 3, June 20, 1923, A. Herb., all these numbered 3, the type; Pippin Point, *Ashe*, April 25, 1925, A. Herb.; Pippin Point, *Ashe*, May 29, 1923, A Herb.; Pippin Point, *Ashe*, October 25, 1923, A. Herb.; Turkey Head, *Ashe* 47, April 25, 1923, A. Herb.; Turkey Head, *Ashe* 47, June 13, 1925.

7. TILIA AUSTRALIS Small, Fl. S. E. U. S., 761. 1903.—*T. floridana australis* (Small) Sargent, Bot. Gaz. **66**: 435. 1918. *T. pubescens Aitoni* forma *glabrata* Engler, Monog. *Tilia*, 129, in part, 1909.—Restricted to the rough mountainous region of middle Alabama. It is very common there, and may occur in the mountainous parts of the adjacent states.

The summer-shoots are glabrous (tomentose in *T. floridana*); flowers very large (very small in *T. floridana*); inflorescence not widely spreading in fruit (wide-spreading in *T. floridana*); pedicels glabrous or glabrate at flowering time (permanently tomentose in *T. floridana* and *T. alabamensis*); bracts glaucous; leaves large, thick, glaucous beneath.

Sargent, in his *Tilia* paper and in his Manual of Trees, does not recognize this as a species; but in this he has done the species a great injustice, as it is better separated from *T. floridana* than is his *T. nuda* (*T. leucocarpa* Ashe).

ALABAMA: Warnock Mountain Summit, Blount County, *C. Mohr*, June 26, 1895, *type* or *co-type* of *T. australis*, U. S. N. Herb. No. 774633. labeled *T. heterophylla*, the *heterophylla* drawn through with pencil and *Amer.* written above it; Addison to Houston, along the road, *Ashe* 80, May 27, 1925, A. Herb.; Addison to Moreland, along the road, *Ashe* 80, May 27, 1925, A. Herb.; Addison to Moreland, along the road, *Ashe* 75, May 27, 1925, A. Herb.; Addison to Moreland, along the road, *Ashe* 37, May 27, 1925, A. Herb.; Double Springs, *Ashe*, June 10, 1925, A. Herb.; Lawrence County, *Ashe*, May 26, 1925, A. Herb.; Lawrence County, *Ashe* 35, May 25, 1925.

8. TILIA HYPOLEUCA (Sargent) Ashe, Bull. Charleston S. Car. Museum 31. 1925.—*T. floridana hypoleuca* Sargent, Bot. Gaz. **66**: 436. 1918.—Missouri and Arkansas, in the Ozark region, apparently a highland species.

Sargent at one time regarded all the glaucous, large-leaved *T. floridana* material from Arkansas and southern Missouri as *T. australis*.

Ashe, in his description of *T. hypoleuca*, does not mention

Sargent's var. *hypoleuca*, but his description is of that form, and he has written me that the two are the same.

The glabrous summer-shoots, the larger flowers, and the glaucous or glabrous, broad, large leaves, distinctly separate this from *floridana;* but I am not sure this is anything more than a glabrous form of *T. heterophylla tenera* Ashe, the *T. Michauxii* of authors, not Nuttall, 1842.

MISSOURI: Galena, *Palmer* 5648, U. S. N. Herb. No. 588394, labeled *T. americana* L., in ink, but the *americana* crossed out with pencil and *australis* penciled above it by Sargent; Eagle Rock, *Palmer* 6311, July 17, 1914, U. S. N. Herb. No. 588616, labeled *T. Michauxii* Nutt., but the *Michauxii* crossed out with pencil and *australis* penciled above it by Sargent; Branson, *Palmer* 5896, June 8, 1914, U. S. N. Herb.; Branson, *Palmer* 5896, June 8, 1924, A. A. Herb.; Mansfield, *Palmer* 6254, July 10, 1914, A. A. Herb.; Galena, *Palmer* 10565, July 25, 1916, A. A. Herb.; Elk Springs, *Palmer* 4285, September 11, 1913, A. A. Herb.; Eagle Rock, *Palmer* 6287, July 16, 1914, A. A. Herb.; Galena, *Palmer* 4616, October 10, 1913, A. A. Herb.; Galena, *Palmer* 10566, July 25, 1916, A. A. Herb.; Eagle Rock, Bush 3211, August 10, 1905, A. A. Herb.; Noel, *Bush* 5983, October 8, 1909, A. A. Herb.—ARKANSAS: Cotter, *Palmer* 5943, June 12, 1914, A. A. Herb., TYPE of *T. floridana hypoleuca* Sargent; Cotter, *Palmer* 10555, July 24, 1916, A. A. Herb., from type station; Cotter, *Palmer* 10559, July 24, 1916, A. A. Herb., from type station; Pine Creek, *Ashe* 43, May 8, 1924, A. Herb.; Pine Creek, *Ashe* 47, May 13, 1924, A. Herb., type of *T. hypoleuca* Ashe; Creek Mountains, Montgomery County *Pope*, May 2, 1924, A. Herb.; Clinton, *Ashe*, September, 1923.

9. TILIA COCKSII Sargent, Bot. Gaz. **66**: 437. 1918.—Louisiana, and probably elsewhere along the coast, as it appears to be a lowland or coastal species.

Summer-shoots are tomentose or pubescent; leaves beneath and bracts when young are tomentose; leaves are dark blue-green, extremely oblique at base; leaves and bracts are floccose-pubescent when they first appear; flowers appear in April.

Sargent says of this species, "leaved subcoriaceous, covered below with articulate hairs when young, finely serrate, bluish-green and lustrous below; tufts of Axillary hairs small or wanting; summer-shoots pubescent; flowers opening the middle of May, 6 mm. long, on tomentose pedicels, in compact pubescent, many-flowered cymes; twigs slender, dull red; buds ovoid, acute, dull red."

LOUISIANA: Lake Charles, *Sargent*, March 26, 1911, U. S. N. Herb. No. 586820, labeled *T. leiophylla* Small; from type trees of *T. Cocksii.*

10. TILIA FLORIDANA Small, Fl. S. E. U. S., 761. 1903.—*T.*

pubescens var. A. *Aitonii* forma *glabrata* Engler, Monog. Tilia, 129. 1909, in part.—*T. Carolinians* var. B *floridana* (Small) Engler, Monog. *Tilia*, 132. 1909.—*T. floridana* Ashe, Sargent, by error, in Bot. Gaz. **66**:431. 1918, and in Manual of Trees of N. Am., 737. 1922.

A lowland or coastal species having a greater range than any species of *Tilia* in North America, excepting the type-species, *T. glabra*, ranging from eastern North Carolina to Georgia, Florida, Alabama, Louisiana, extreme southwestern Arkansas, eastern and southern Texas, and perhaps northeastern Mexico; the trees of Missouri, Kansas, and the elevated portions of Arkansas, Oklahoma and Texas belong more properly to *T. alabamensis*, a species more closely related to *T. glabra*.

T. floridana has permanently pubescent pedicels, small flowers, narrow sepals, narrow leaves, usually unsymmetrical and glaucous beneath, mostly ovate fruit and slender twigs; leaves are longer and narrower than those of *leucocarpa*.

This species appears to be confined to the long-leaf pine region. The greater part of the material from Missouri, Arkansas, Oklahoma and Texas referred by Sargent to *T. floridana*, appears to me to be either *T. alabamensis* or *T. leucocarpa brevipedunculata*.

Sargent describes *T. floridana* Ashe in his *Tilia* paper in the Botanical Gazette and in his Manual of the Trees of North America; but this is an error, as the species was described by Small in his Flora in 1903. Under *T. creno-serrata* Sargent cites as synonym, *T. floridana* Sargent, not Small, leaving it to be inferred that there was a *T. floridana* of Small, different from the *T. floridana* Ashe.

Sargent states that the summer-shoots of *T. floridana* are glabrous, which shows that it was very evident that he had seen no specimens of it from western Florida (type locality), where all the trees have tomentose or pubescent summer-shoots. It is very evident that Sargent mistook *T. alabamensis* for this species.

Sargent says of this species, "flowers 5–6 mm. long (*flowers of T. alabamensis 10–12 mm. long*), on hoary tomentose pedicels; fruit ripening in August and September, subglobose, or ellipsoid, rusty-tomentose, 12.5 mm. in diameter; leaves below with articulate hairs when young; summer-shoots not pubscent (*T. alabamensis is here disclosed, the real T. floridana having tomentose or pubescent summer-shoots*); leaves with or without tufts of axillary hairs, green or glaucescent beneath; twigs red-brown or yellow; buds obtuse."

I have devoted more space to this species, perhaps, than the occasion warrants, but I wish to establish the identity of a species that has been obscured in Sargent's publications. In Sargent's paper on *Tilia*, published 1918, several different forms are referred to the species *T. floridana*, thereby obscuring the identity of what really is a very distinct species.

ALABAMA: Jackson, *Dr. Henry*, August 24, 1888, from Mohr Herb., U. S. N. Herb. No. 774634, labeled *T. Americana* L.—MISSISSIPPI: De Soto, *C. Mohr*, June 5, 1894, from Mohr Herb. U. S. N. Herb. No. 774635, labeled *T. Americana* L.—FLORIDA: Jackson County, *Curtiss* 401, June, type-specimen or co-type, U. S. N. Herb. No. 13520, labeled *T. Americana* L. var. *pubescens* Gray; Choctawhatchee, *Ashe* 2, October 25, 1923, A. Herb.; Bear Creek Head, *Ashe* 16, June 6, 1925, A. Herb.; Bear Creek Head, *Ashe* 16, June 6, 1925, A. Herb.; Bear Creek Head, *Ashe* 16, June 6, 1925, A. Herb.; Bear Creek, *Ashe* 16, June 6, 1925, A. Herb.; Bear Creek Head, *Ashe* 19, 1925, A. Herb.; Bear Creek Head, *Ashe* 19, June 6, 1925, A. Herb.; Turkey Creek Head, *Ashe* 23, May 29, 1923, A. Herb.; Turkey Creek Head, *Ashe* 23, November 7, 1924, A. Herb.; Turkey Creek Head, *Ashe* 24, June 1, 1923, A. Herb.; Mariana, *Bilt, Herb.*, April 20, 1899, from Bilt, Herb., U. S. N. Herb. No. 960276, labeled *T. Americana* L.—LOUISIANA: Many, *Ashe* 2, October 13, 1921, A. Herb.; Many, *Ashe* 2, June 18, 1925, A. Herb.; Many, *Ashe* 2, March 30, 1925, A. Herb.; Many, *Ashe* 2, March 30, 1925, A. Herb.; Many, *Ashe* 2, September, 1925, A. Herb.—ARKANSAS: Fulton, *Bush* 5647 B, May 19, 1909, U. S. N. Herb. No. 587107, labeled *T. leiophylla* by Bush; this locality is probably the northern limit of this species.

11. TILIA ALABAMENSIS Ashe, Bull. Charleston S. Car. Mus. 14. October 24, 1918.—*T. floridana* Sargent, in large part, Bot. Gaz. **66**: 431, 1918, and Manual of the Trees of N. Am., 737, 1922, not Small, 1903.—*T. Floridana alabamensis* Ashe, Bull. Charleston S. Car. Mus. June 30, 1925.—Alabama and Georgia to Louisiana, Arkansas, Missouri, and Texas. This is the northern tree of the more elevated regions, with round-ovate, tomentose or cordate leaves, acute buds and glabrous summer-shoots.

Ashe says of this species,[6] "since the flowers of this form seem so much like those of *floridana*, it at present seems best to consider this as a long-leaved variety of that species, notwithstanding its different habitat, growing in swamps, whereas *floridana* is a tree of well-drained sites."

I wish to record my objections to these statements, as the flowers of *T. alabamensis* are large, much like those of *T. glabra*, the leaves are broad and short, not long and narrow, and the trees do not grow in swamps or low ground, but along shaded creeks and river banks in rich soil.

ALABAMA: Boligee Swamp, Boligee, *Ashe*, August 1918, TYPE, A. Herb.; Boligee Swamp, Boligee, *Ashe*, October 22, 1923, A. Herb.; Greensboro, *Miss Dew*, 1924, A. Herb.; Greensboro, *S. A. Dew*, 1925, A. Herb.—OKLAHOMA: Page, *Stevens* 2669, September 18, 1913, U. of Ill. Herb.; Lenapah, *Steven* 2171, August 19, 1913, U. of Ill. Herb.—ARKANSAS: Mill Creek, *Ashe*, April 28, 1924, A. Herb.; Walnut Tree, *Ashe* 22, September 20, 1925, A. Herb.; Worcester, *Ashe* 11, September 23, 1925, A. Herb.; Worcester, *Ashe* 11, September 23, 1925, A. Herb.—MISSOURI: Greenwood, *Bush* 9594, September 10, 1921, D. Herb.; Greenwood, *Bush* 9594, September 10, 1921, U. of Ill. Herb.; Greenwood, *Bush* 9594 A, September 10, 1921, U. of Ill. Herb.; Greenwood, *Bush* 9798, June 23, 1922, U. of Ill. Herb.; Greenwood, *Bush* 9798, June 23, 1922, U. of Ill. Herb.; Greenwood, *Bush* 9798, June 23, 1922, U. of Ill. Herb.; Greenwood, *Bush* 9798, June 23, 1922, D. Herb.; Greenwood, *Bush* 9798A, June 23, 1922, U. of Ill. Herb.; Greenwood, *Bush* 9798A, June 23, 1922, U. of Ill. Herb.: Dodson, *Bush* 9732, October 11, 1921, U. of Ill. Herb.; Galena, *Palmer* 10566, July 25, 1916, A. A. Herb.; Poplar Bluff, *Palmer* 6180, July 4, 1914, A. A. Herb.; Monteer, *Bush* 9283, U. of Ill. Herb.

11A. TILIA ALABAMENSIS OBLONGIFOLIA (Sargent) n. comb. *T. floridana oblongifolia* Sargent, Bot. Gaz. **66:** 435. 1918.—Florida and Alabama to Louisiana, extreme southwestern Arkansas and northeastern Texas, if no misidentifications of specimens have been made, therein occupying nearly the same range as *T. floridana*. The ovate-oblong leaves, the more prominent tufts of axillary hairs, the slender glabrous, reddish-brown branchlets seem to separate it from *floridana;* but that it is a variety of *T. alabamensis*, I am not sure, and further observations and collections may prove that it is only a form of *T. floridana*.

COURTNEY, MISSOURI.

The gametophytic development of certain ferns: Polypodium vulgare var. occidentale and Pellaea densa[1]

F. L. Pickett and Lewis A. Thayer

(With plates 15–17)

POLYPODIUM VULGARE L. VAR. OCCIDENTALE HOOKER

In following the gametophytic development of this fern, five cultures were grown on Knop's solution, and two on soil obtained from Kamiak Butte. Two of the water cultures were kept in the laboratory; all others were kept in a shaded part of the greenhouse. Spores were obtained from fronds collected at Renton, Washington, in November, 1924. These were sown on December 3 and 4, 1924.

When dry, the spores were bright yellow, reniform, 50–60 × 30–40 microns, with walls 3–4 microns thick, including the papillose protuberances which cover the surface. On the flattened side, the papillae are less conspicuous, and the total thickness of the wall is less. The spore probably breaks at this point upon germination (plate 15, fig. 1). The spores contained small oil globules, but no chlorophyll, but within six days after sowing, they showed a distinct green color, and the oil globules had increased in size and number. Germination was practically 100 per cent perfect. On the seventh day, some of the spores showed the appearance of a short rhizoid (plate 15, fig. 2). A day or so later, the extine burst further, the intine protruded, and a cell was cut off (plate 15, fig. 3). This cell possesssed chloroplasts, but the rhizoids did not.

Growth and cell division continued in the same plane until a protonema-like structure of four (occasionally but three) cells was produced (plate 15, figs. 4–6). The second cell from the spore then divided parallel to the long axis of the prothallium (plate 15, fig. 6). Similar divisions quickly followed in the third and fourth cells (plate 15, figs, 7, 8). Division in the third cell occasionally preceded division in the second. The cell next to the spore usually remained undivided, but not always (plate 15, fig. 9). In the cultures in the green house, where the light was less intense than in the laboratory, the protonema-like chain was prolonged more or less, even up to thirteen or fourteen cells (plate 16, figs. 5, 16).

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[1] Contribution No. 7 from the Department of Botany of the State College of Washington.

One or both of the cells produced from the terminal cell then divided, forming a cell wall either from the outer wall to the median wall, or from the outer wall to the transverse wall (plate 15, figs. 9. 10). If the division in one of the cells occured as in figure 12 (plate 15), from the median wall to the transverse wall, a more symmetrical type of prothallium resulted (plate 15, fig, 13). Such forms were not uncommon, and in later stages were not to be distinguished from the prothallia produced by the first method. Similar divisions frequently occurred in the daughter cells arising from the third cell of the prothallium, and sometimes in the second.

Usually but one of the daughter cells arising from the terminal cell became active (plate 15, figs. 11, 14–17). Within a short time the inactive cell often cut off a small hyaline cell on the outer corner (plate 15, fig. 15), the first of the projections, trichomes, which occurred at intervals around the margin in the mature prothallium. No one definite apical cell was found, growth being by means of a meristematic group (plate 15, figs. 16, 17; (plate 16, fig. 2), All of the cells of the prothallium retained the power of tangential division. A sinus shortly became evident in some of the prothallia (plate 16, figs. 1, 2), but not in others (plate 16, fig. 8). The former eventually developed into the cordate shape shown in figure 3 (plate 16); the latter into the spatulate shape shown in figures 7, 11 (plate 16). The water cultures in the reduced light of the greenhouse tended to produce the latter type almost exclusively. In both, as the drawings show, the first three cells of the prothallium, or the few cells derived from them, remained easily distinguishable.

Apparently the Knop's solution did not furnish a normal medium for growth: many odd forms were produced (plate 16, figs. 4–6 12, 16); and neither antheridia nor archegonia were produced in these cultures.

About the second week in March, all of the prothallia on the soil cultures began to produce antheridia (plate 16, figs. 9, 15, 20); the development of the latter being as described by Atkinson (1, p. 17), and Campbell (2, pp. 314–318) (plate 16, figs. 10, 17, 21, 22). Antheridia were produced as long as the culture was under observation, up to the third week in May. At first the cells near the spore were involved, then the cells farther and farther out produced antheridia, until finally the cells in the wings, well beyond the sinus, also bore them. A large number of the cells bore two antheridia each (plate 16, fig. 14)

Within from seven to ten days after the antheridia appeared, archegonia began to appear on the cordate prothallia just behind the sinus. They were club-shaped, only slightly curved, and were similar in their development to those described by Atkinson (1, pp. 12–15), and Campbell (2, pp. 318–319) (plate 16, figs. 13, 18, 19). As many as fifteen archegonia were produced on a single prothallium, but only one sporophyte was observed to develop. The cushion was limited to the area immediately beneath the archegonia, and was but three or four cells thick at the most.

By April 29, minute fronds had appeared which grew normally until about July 15, when the cultures were allowed to dry up. They remained dry until about the first of October, when they were watered again. The fronds and prothallia revived and apparently resumed normal growth. Repeated dryings finally killed them.

PELLAEA DENSA (BRACK.) HOOKER

Spores were obtained from specimens collected July 18, 1925, on peridotite ledges in Van Epp's Pass (Wenatchee Mountains) by Dr. Harold St. John, and were sown on two saucers of sterilized soil. The spores were colorless, nearly round, 45–55 × 40–50 microns with unevenly ridged surfaces (plate 17, fig. 1).

The cultures were started on November 5, 1925, but germinated very slowly, requiring from two to three weeks before showing green. Development was quite similar to that in *Polypodium vulgare* var. *occidentale* (plate 17, figs. 2–4), except that fewer odd forms were produced (plate 17, figs. 8, 9).

By December 8 in most cases, each prothallium began to develop a sinus. For a time the two lobes developed unequally (plate 17, figs. 4–6), but eventually nearly all became symmetrical (plate 17, fig. 11). Most of the prothallia assumed a cordate shape, although a few remained spatulate (plate 17, fig. 7). The latter were all male prothallia (plate 17, fig. 18); not all male prothallia were spatulate, however.

About January 20, antheridia and archegonia appeared almost simulteneously, but on separate prothallia. In the main, their development followed the method outlined by Atkinson (1, pp. 12–15, 17) and Campbell (2, pp. 314–319) (plate 17, figs. 15–17; 10, 12, 14). As the antheridium matured, the cap cell seemed to split into quarters, opening a four-sided pore in the middle (plate 17, fig. 15). By January 25, swimming sperms were very numerous, and were produced continuously thereafter up to May 26, when the last observation was made. The archegonial prothallia of *Pellaea densa* differed from those of *Polypodium vulgare* var. *occidentale*, in that in the latter the cushion was exceedingly thin—but two to four cells thick—and was very limited in extent. In *Pellaea densa*, however, the archegonial cushion was large and conspicuous, and the egg cell was located well within the cushion (plate 17, fig. 14). As the archegonium reached maturity, the egg and canal cells turned dark brown and became very conspicuous, making drawing without sections comparatively easy.

By February 15, the first leaves of the sporophytes had begun to make their appearance. By April 17, when the second leaves began to appear, the first frond had attained a diameter of 4–5 mm., and a height of about 1 cm.

On May 25 an archegonial prothallium was found without a sporophyte, in which the cushion had resumed active growth, producing a new prothallium; but the regenerated tissued produced antheridia instead of archegonia. Antheridia were found even among the old archegonia (plate 17, fig. 13). In the drawing the egg cells are represented by small stippled ovals. The thickness of the cushion prevented the drawing of all of the cells Another prothallium was seen with a similar regenerated area, but it was producing only new archegonia.

The behavior of *Pellaea densa*, in thus producing sporophytes by the normal sexual method, was rather surprising, inasmuch as the production of apogamous sporophytes is reported for several other members of the genus, viz., (*P. adiantoides* J. Sm. (9, 10); *P. atropurpurea* (L.) Link (4, 8); *P. atropurpurea cristata* Trelease (10, 11); *P. flavens* (Sw.) C. Chr. (12, 13); *P. glabella* Mett. (7); *P. hastata* L. (11); *P. nivea* (Poir.) Prantl (5); *P. tenera* (Gill.) Prantl (12, 13); and *P. virides* (Forksk.) Prantl (10). In an effort to induce apogamous embryos, one of the cultures was allowed to become dry a number of times. Although a considerable number of prothallia were examined, no evidence of apogamous embryos was found. Those prothallia which had not developed sporophytes by May 25 were still producing sex organs abundantly. On May 12, about fifty archegonia of various ages were counted in the low power field (diameter, 1.7 mm.) of the microscope, which did not include all of the cushion. Antheridia were even more numerous, between fifty and sixty having been counted in the high power field (0.39 mm. in diameter). Living sperms were seen on May 12, and again on May 25.

Pellaea densa has been transferred by Diels (3) to *Cryptogramma*, and has recently been renamed *Cheilanthes siliquosa*, by Maxon (6) on the ground that, though it is not a typical *Cheilanthes*, still its natural affinity is more with that group than with the other Pellaeas. Maxon's disposition is temporary, pending a more careful study of this species and some others, which he suggests may be better segregated in a new genus. However that may be, the segregation of *Pellaea densa* with its normal sexual development, from a genus in which an apogamous origin of the sporophyte seems to be the usual thing, seems quite logical.

Literature cited

1. **Atkinson, G. F.** The study of the biology of ferns by the collodion method. 1894.
2. **Campbell, D. H.** The structure and development of mosses and ferns. 1905.
3. **Diels, L.** In: Engler and Prantl. Naturlichen Pflanzenfamilien. **1⁴**: 280. 1899.
4. **Hayes, D. W.** Some studies of apogamy in *Pellaea atropurpurea* (L.) Link. Trans. Amer. Mic. Soc. **43**: 119–131. *pl. 3, 4.* 1924.
5. **Goebel, K.** Aposporie bei *Asplenium dimorphum*. Flora **95**: 239–244. *f. 1–3.* 1905.
6. **Maxon, W. R.** Notes on American ferns. XII. The systematic position of *Pellaea densa*. Amer. Fern Jour. **8**: 114–116. 1918.
7. **Pickett, F. L., and Mildred E. Manuel.** Development of prothallium and apogamous embryos in *Pellaea glabella* Mettenius. Bull. Torrey Bot. Club **52**: 507–514. *f. 1–32.* Jan. 6, 1926.
8. **Steil, W. N.** Apogamy in *Pellaea atropurpurea*. Bot. Gaz. **52**: 400–401. 1911.
9. ————. Some new cases of apogamy in ferns. Preliminary note. Science **41**: 293–294. 1915.
10. ————. Studies of some new cases of apogamy in ferns. Bull. Torrey Bot. Club **45**: 93–108. *pl. 4, 5.* 1918.

11. ———. A study of apogamy in *Nephrodium hirtipes* Hk. Ann. Bot. **33:** 109–132. *pl. 5–7.* 1919.

12. **Wesselowska, Helene.** Apogamie und Aposporie bei einigen Farnen. Ber. Deut. bot. Gesellsch. **25:** 85–86. 1907.

13. **Woronin, Helene (Wesselowska).** Apogamie und Aposporie bei einigen Farnen. Flora **98:** 101–162. *f. 1–72.* 1908.

Explanation of plates

All figures are from camera lucida drawings made with a Spencer microscope.

PLATE 15

POLYPODIUM VULGARE VAR. OCCIDENTALE

1. A spore. × 336.

2. A germinating spore with rhizoid. × 248.

3. A germinating spore with rhizoid and germ tube. × 248.

4. A germinating spore with two prothallial cells. × 248.

5. A germinating spore with three prothallial cells. × 248.

6. A germinating spore with four cells in a protonema-like chain, the second cell being divided longitudinally. × 248.

7. A young prothallium with longitudinal divisions in the second and third cells. × 248.

8. A young prothallium with longitudinal divisions in the second, third and fourth cells. × 248.

9. A young prothallium with longitudinal divisions in all four cells—a less common form than those of 7 and 8. The first cell wall in the daughter cells arising from the end 'protonema' cell formed. This is the most common direction of this first division. × 84.

10. A young prothallium illustrating the less common method of cell wall formation from the outer wall to the transverse wall. × 84.

11. A normal young prothallium resulting from the development of but one of the daughter cells from the end 'protonema' cell. × 84.

12. A young prothallium with the unusual method of cell wall formation from the median wall to the transverse wall. × 84.

13. The symmetrical type of prothallium resulting from such a form as is shown in 12. × 84.

14. A young prothallium. × 84.

15. A young prothallium with the first trichome formed. × 84.

16, 17. Stages in the development of the normal prothallium. Both × 84.

PLATE 16

POLYPODIUM VULGARE VAR. OCCIDENTALE

1. A young prothallium showing the appearance of the sinus. × 84.

2. An older prothallium with the sinus further developed. × 62.

3. A normal cordate prothallium. × 62.

4, 5, 6, 12, 16. Odd forms of prothallia produced in Knop's solution in the weak light of the greenhouse. All × 62.

7, 8, 11. Spatulate prothallia of the type which produced antheridia only. All × 62.

9. A cordate prothallium bearing antheridia. × 62.

10. A longitudinal section through a young antheridium. × 248.

13. The neck of an opened archegonium showing the lid-like cap cell. × 248.

14. A portion of a prothallium, showing some of the cells bearing two antheridia each. × 62.

15. A spatulate prothallium with antheridia. × 62.

17. An opened antheridium, showing the pore. × 248.

18. An archegonium almost mature, but unopened. × 248.

19. A cross-section of the neck of an archegonium. × 248.

20. A protonema-like prothallium bearing antheridia. × 62.

21. A longitudinal section through an antheridium. × 248.

22. A longitudinal section through the pore of an opened antheridium. × 248.

PLATE 17

PELLAEA DENSA

1. A spore. × 336.

2, 3, 4. Young prothallia. All × 62.

5, 6. Cordate prothallia with unequal wings. Both × 62.

7. A spatulate prothallium. × 62.

8. A prothallium showing a sinus, but with one wing undeveloped. × 62.

9. An odd form, showing regeneration of the prothallium from a single cell. × 62.

10. A group of immature archegonia. × 138.

11. An immature prothallium illustrating the mature shape. × 62.

12. A cross-section of the neck of an archegonium. × 138.

13. Tissue formed by the regeneration of cells in the cushion of an old prothallium, the new tissue bearing antheridia. The egg cells of the old archegonia are represented by the small stippled ovals. × 62.

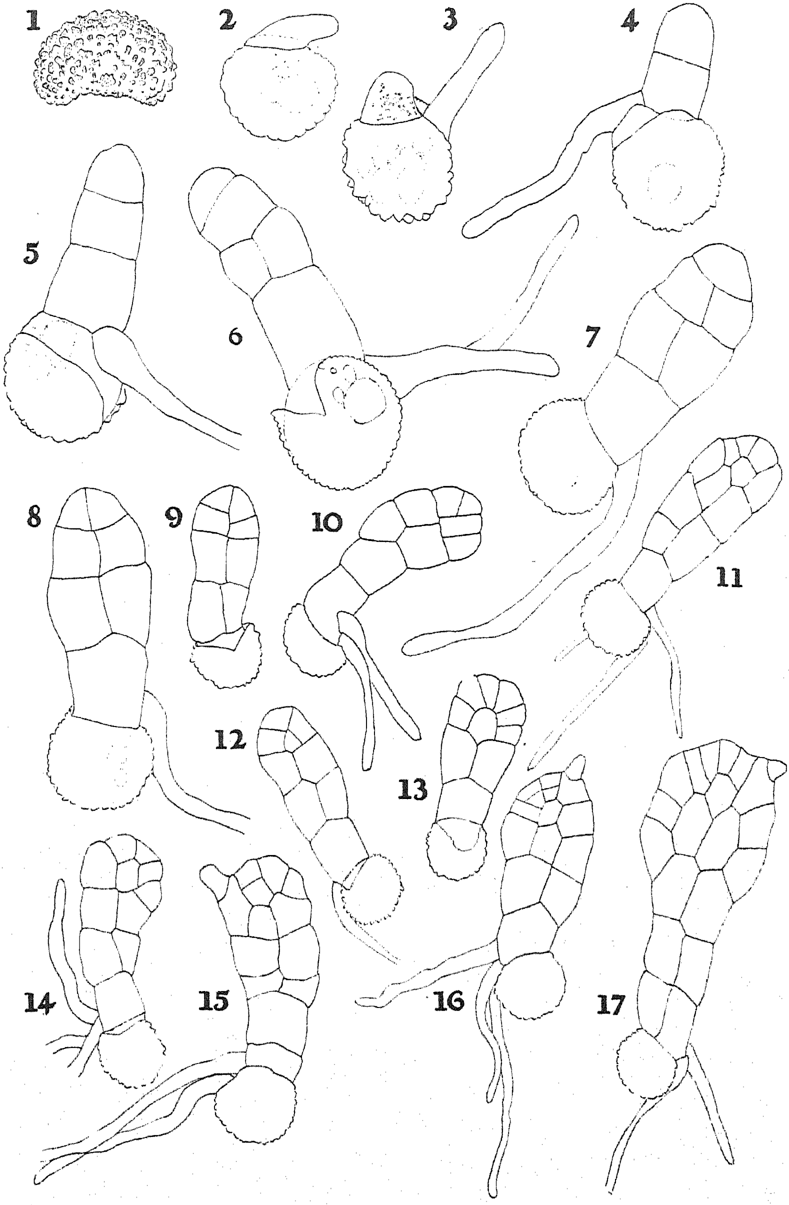
14. A longitudinal section of an opened archegonium. The stippled area represents the portion which is dark brown in the fresh material, and which makes the archegonia so conspicuous. × 138.

15. An opening antheridium, showing how the cap cell splits to form the pore. Seen from above. × 248.

16. An unopened antheridium as seen from above, showing the cap cell. × 248.

17. A group of unopened antheridia in longitudinal section. × 248.

18. A small antheridial prothallium. × 62.



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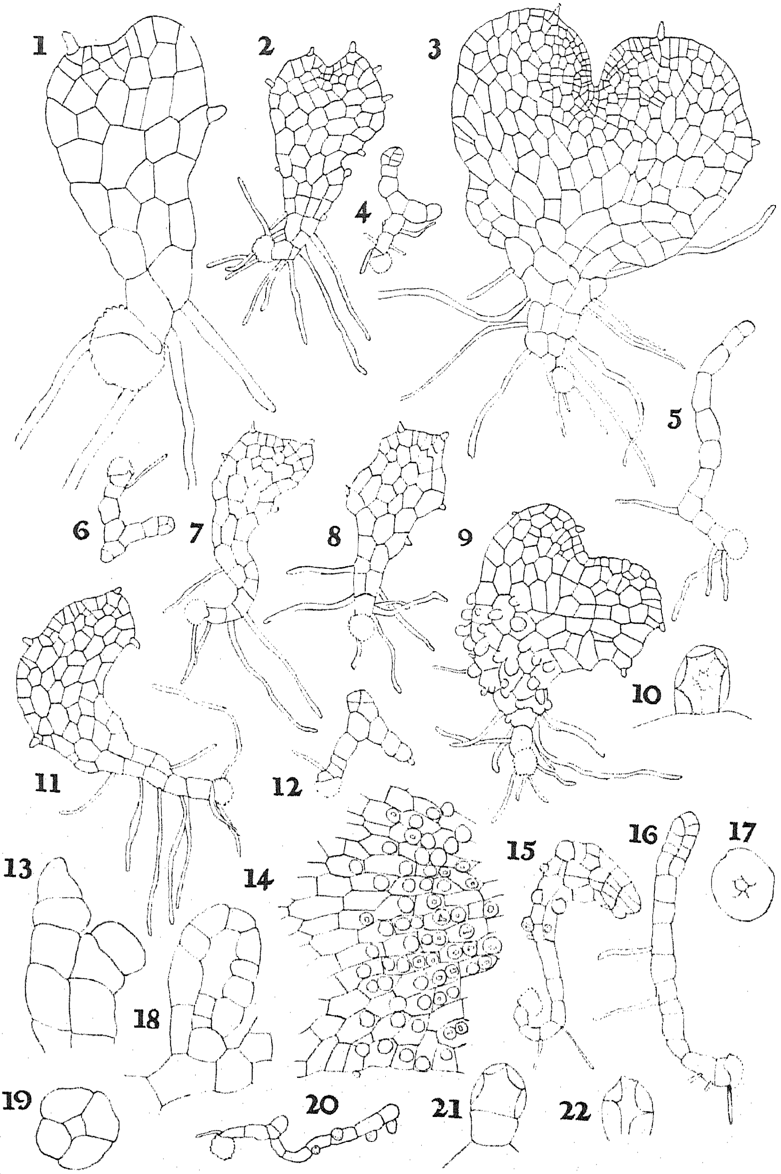

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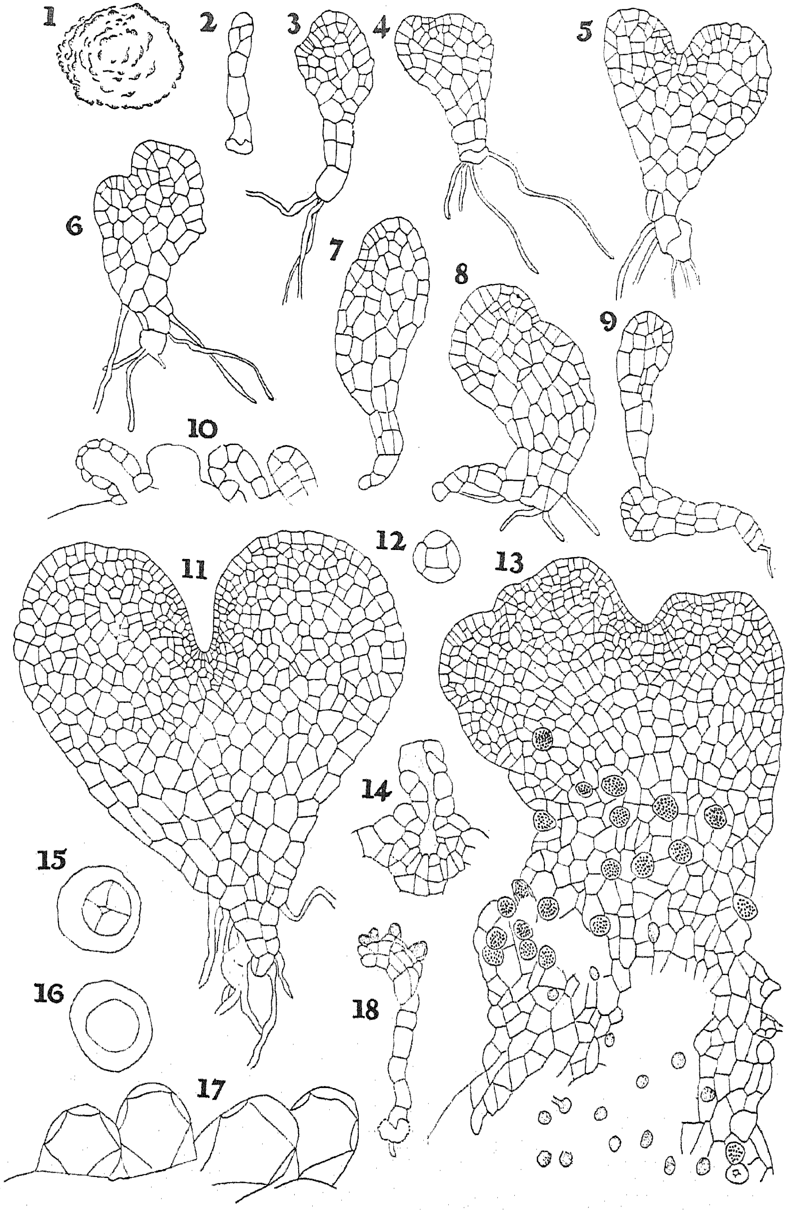

PELLAEA DENSA

A new Sagittaria from Florida: Sagittaria Kurziana

HUGO GLÜCK

The new species was found on two automobile trips with Dr. Herman Kurz to Wakulla County, in northwestern Florida, on March 11 and 22, 1926. Two localities for it are the so-called Upper and Lower Bridges of the Wakulla River. A third station for it was the St. Marks River at Newport. Both streams unite somewhat below St. Marks, from where they empty into the Gulf of Mexico. All localities for it are in forests characterized by cypress (*Taxodium distichum*) and cabbage palm (*Sabal Palmetto*).

At the first locality the plant forms the dominant vegetation of the clear running water between the two bridges referred to above, as is easily seen. Lesser associates of the *Sagittaria* are *Vallisneria americana*, *Ceratophyllum demersum* and *Potamogeton* spp. Since this *Sagittaria* has apparently not been described, I shall name it after Dr. Herman Kurz, professor of botany in the Florida State College for Women, who took me to the locality.

The original work on the genus *Sagittaria* and *Lophotocarpus* was published by Jared G. Smith.[1] The later authors[2] who dealt with this family added little new to Smith's work. The new species about to be described is a near relative of *S. subulata* (L.) Buchenau and *S. lorata* (Chapm.) Buchenau (= *S. natans* Michx.).[3]

S. Kurziana forms a rhizome in the substratum of the stream which consists of a large number of white subterranean internodes ranging from 19.5–32 cm. in length and 2–4.2 mm. in diameter. From the nodes rise 5–15 strap-like leaves, which are described as phyllodia by American botanists. From a morphological standpoint, these leaves should be designated as primary leaves, which correspond to the submerged leaves of other Alismaceae and those of many other water plants.[4] The leaves have the extraordinary length of (60) 90–164 cm. and a diameter of (4) 7.5–15.5 mm. Some plants found in the St. Marks River at Newport were even twice as long, as we shall presently see. The phyllodia taper gradually toward the tip, and are broadest above the middle. They are marked by three (rarely five) prominent ridge-like nerves; only on narrow leaves are the lateral veins inconspicuous.

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[1] Jared G. Smith. A revision of the North American species of *Sagittaria* and *Lophotocarpus*. Ann. Rep. Missouri Bot. Garden **6**: 27–64. *pl. 1–29.* 1895.

[2] John K. Small. Alismaceae. North American Flora **17**: 43–62. 1909.
John K. Small. Flora of the Southeastern United States. 2d ed. New York, 1913.

[3] It should be noted that the American *S. natans* Michx. would be more properly called *S. lorata* (Chapm.) Buchenau, since the *S. natans* Pallas is an arctic plant of the Old World, and must not be confused with the American plant.

The cross-section of a medium-sized leaf shows the following. The main nerve consists of three bundles in a vertical row, of which the middle one is the largest. The margin is thickened. The two prominent nerves and the margin contain only one nerve. The section contains about 40 oval or round air channels which are surrounded with thick parenchyma. The section shows many droplets of milky juice. The phyllodia of *S. lorata*, on the other hand, are thickened in the middle and taper gradually to a thin margin. Then, too, the leaves contain five bundles, which never form ridges as in the case of *S. Kurziana*. Also there are about 25 air channels which are either square or polygonal, and which are surrounded by only one layer of parenchymatous cells. The leaves are relatively soft and show in cross-section no milky juice.

The solitary flowering scapes are also floating and 100–142 cm. long, or even 250 cm., as in the case of the Newport locality. The scape is thickest below the inflorescence, where it attains a diameter of 3–4 mm., whence it tapers toward the base to a thickness of 1.2–2 mm. The whole inflorescence itself is about 27–48 cm. long; it is simple and consists of whorls of three, or one finds in the lower whorl instead of a flower a branch of varying length; only once was it noticed that the lowermost whorl contained two branches and one flower. In the branched inflorescence one often finds the lowermost whorl in twos. Apparently in such cases the second flower is not developed.

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[4] Concerning the prevalence of the primary leaves and their significance for the higher water plants, see H. Glück: Morphologische und biologische Untersuchungen über Wasser und Sumpfgewächse. Vol. I–IV. 1905–1924. (Gustav Fischer's Verlag in Jena.)

The simple inflorescence, or each branch, is divided into 4–9 internodes which are 0.8–17 cm. long and 1–3 mm. thick. The coalescent bracts are 1.1–3.6 cm. long and more or less persistent.

The lowest whorl contains sometimes three female flowers, sometimes two female flowers and one male. The next to the lowest contains as a rule only male flowers or rarely one male and two female flowers, or vice versa. All remaining flowers are male. The pedicels of the female flowers run from 5–15.3 (rarely 25.5) cm. long, and are 1.5–2.8 mm. thick. After flowering the pedicels recurve. The female flower is about 18 mm. wide; the petals are pure white and short clawed. The sepals are broadly ovate and about one half as long as the nearly round petals. The head of the carpels is about 4.5 mm. thick. The carpels are oval and the style points obliquely upwards. The stigmatic surface is oblique with reference to the style, and is covered with forward pointing pellucid papillae. Mature fruits are up to the present unknown, but the half ripe carpels show a more or less irregular crest and some isolated tubercles in the sides.

The pedicels of the male flowers are 4–12.5 cm. long and 0.5–1.2 mm. thick. The flower is 17–25 mm. wide. The three sepals are oval, dark green and herbaceous, and one half to one third as long as the petals. The number of the stamens ranges from 8–13. The filaments are glabrous and distinctly enlarged; they are as long as, or longer than, the anthers. In the second locality at Newport I was able to obtain nothing but a few plants which had been torn from the bottom of the river. Five rootstocks had 8–9 strap-like leaves with a length of 240–334 cm. and a width of only 4–8 mm. These, however, were marked with only one prominent middle nerve, only a few showing three distinctly raised nerves. But the margins were thickened as in the case of the Wakulla plant. In regard to the tapering, cross-section, the distribution of air channels, bundles and milky juice of the leaves, no difference was noted. Among the floating leaves two flowering scapes were found; one had lost its inflorescence but was nevertheless 234 cm. long. If we allow 30 cm. for the inflorescence we can estimate the total length of the scape to be about 260 cm. From the measurements obtained from this locality the writer believes *S. Kurziana* to be the longest species in America.

Further *Sagittaria Kurziana* is, as far as I know, the largest *Sagittaria* of the whole world! And the only form among the whole genus which approaches it in shape and size is the submerged and strap-like-leaved form of the European *S. sagittifolia* (= S.s. forma vallisneriifolia Cossonet Germain) which grows in deep and running water of the Rhine valley. Its leaves become 110–216 cm. long and (12)17–25 mm. broad, and the scapes become 152–204 cm. long. Further, see my former account of this interesting plant.[5]

Finally, the differences between *S. Kurziana* and *S. lorata* (Chapm.) Buchenau (= *S. natans* Michx.) might be summarized:

1. The leaf of *S. Kurziana* may be three times the length of that of *S. lorata*.

2. The leaf of *S. Kurziana* always shows 1–5 prominent ridge-like nerves on its under side and thickened margins, while *S. lorata* has a smooth leaf surface which tapers gradually to a thin margin. The leaf of *S. Kurziana* is relatively firm; that of *S. lorata* is soft. The cross section of *S. Kurziana* shows small round or oval air channels; *S. lorata* on the contrary shows large square or polygonal air channels. The leaf of *S. Kurziana* contains milky juice while *S. lorata* does not.

3. The inflorescence of *S. Kurziana* is often branched; that of *S. lorata* never. The axis of the inflorescence and also its branches have 4–8 whorls; while *S. lorata* produces only one or a few whorls. The flowering scapes of *S. Kurziana* are gradually thickened upwards; in *S. lorata* they are of uniform thickness.

4. The bracts of *S. Kurziana* are 1.1–3.6 cm. long and often persistent; those of *S. lorata* are only a few millimeters long and ephemeral.

5. The flowers of *S. Kurziana* are always larger than those of *S. lorata*.

6. The number of stamens for *S. Kurziana* is 8–13; for *S. lorata* it is 7–8.

7. The writer would point out that *S. Kurziana* is not to be confused with ecological varieties of *S. lorata*. *S. subulata gracillima* (Wats.) Smith[6] is a deep water form of *S. lorata*,

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[5] H. Glück, op. cit., vol. I, p. 210 and 216, pl. VII, fig. 42. And in addition, H. Glück, Alismaceae in Kirchner, Löw and Schröter "Lebensgeschichte der Blütenpflanzen Mittel-Europas," p. 622 and fig. 355.

[6] J. G. Smith *op. cit.*, p. 45.

whose leaves are 60–120 cm. long, only 2 mm. broad, and indistinctly 1-nerved. Likewise, *S. natans lorata* Chapman[7] can be ruled out, because its strap-like leaves are described as nerveless. To the writer this form is a juvenile state of *S. lorata* without floating leaves.

In conclusion the author would like to note that the new plant should be studied more in detail, especially the fruit formation and the adaptation to different environments.

TALLAHASSE, FLORIDA, MARCH, 1926.

SUPPLEMENT

The printing of my article on *Sagittaria Kurziana* has been delayed rather long and therefore I am in a position to add some further observations:

I succeeded in transporting a number of root-stocks of *Sagittaria Kurziana* to the hot-house of the Heidelberg botanic garden.[8] I put these shoots in water 15–25 cm. deep in order to test if *Sagittaria Kurziana* could produce floating leaves like *S. lorata* or not. Between May 20, 1926, and February 28, 1927, the whole plant vegetated but remained small in all parts, and sterile, without forming floating leaves. One shoot bore 4–8 submerged leaves which were (4)8–32 cm. long, and 3.4–7.5 mm. broad; the internodes of the runners between two shoots were 5.2–8.2 cm. long and 1–1.3 mm. thick. Tubers also were not produced. Thus I have further demonstrated that *Sagittaria Kurziana* never represents an unusual submerged form of *S. lorata*. The latter turns immediately into forms with swimming leaves if the conditions are appropriately changed.

HEIDELBERG, GERMANY, MARCH, 1927.

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[7] A. W. Chapman. Flora of the Southern United States. 3d ed. 474. 1897.

[8] I should like to say that Professor True of the University of Pennsylvania had the kindness to keep for me for some time in his hot-house in Philadelphia a number of plants which I sent him during my last excursion in North America. And one day before I sailed from New York I took the material from Philadelphia and I transported it to Germany as quickly as possible.

INDEX TO AMERICAN BOTANICAL LITERATURE

1916–1926

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Abbot, E. V. A study of microbiological activities in some Louisiana soils: a preliminary survey. Louisiana Agr. Exp. Sta. Bull. 194: 1–25. *f. 1.* Je 1926.

Adams, J. F. Plant disease survey of economic crops in Delaware during 1925. Bull. S. Bd. Agr. Delaware 15: 1–28. F 1926.

Allen, C. E. Gametophytic inheritance in *Sphaerocarpos.* III. The genetic uniformity in typical clones. Genetics **11**: 83–87. "Ja" 16 Jl 1926.

Allen, C. E. The transmission of the vegetative character in *Sphaerocarpos.* Trans. Am. Phil. Soc. **65**: 83–89. Ap 1926.

Allen, R. F. A cytological study of *Puccinia triticina* physiologic form 11 on Little Club Wheat. Jour. Agr. Res. **33**: 201–222. *f. 1–9.* 1 Au 1926.

Anderson, D. B. The structure and formation of bast fibers in flax. Science II, **64**: 64–65. 16 Jl 1926.

Anderson, P. J., Osmun, A. V., & Doran, W. L. Soil reaction and black root-rot of tobacco. Massachusetts Agr. Exp. Sta. Bull. 229: 117–136. Ap 1926.

Archer, W. A. Morphological characters of some Sphaeropsidales in culture. Ann. Mycologici **24**: 1–84. *f. 1–18 + pl. 1–8.* 1926.

Arthur, J. C. Uredinales. Additions and corrections (continued). No. American Flora 7^{11}: 733–796. 4 Au 1926.

Artschwager, E. Anatomy of the vegetative organs of the sugar beet. Jour. Agr. Res. **33**: 143–176. *f. 1–23.* 15 Jl 1926.

Ayers, T. T. Selection within a clone of *Helminthosporium sativum* during seven generations. Am. Nat. **60**: 344–346. *f.* 1. Jl–Au 1926.

Baas-Becking, L. G. M., & Baker, L. S. Studies on growth. I. The point binomial and its derivatives. II. Experimental data—application of the theory. Stanford Univ. Publ. Biol. Sci. **4**: 61–135. *f. 1–30.* 1926.

Bakke, A. L., & Plagge, H. H. The extent to which weeds modify the transpiration of cereals. Iowa Agr. Exp. Sta. Res. Bull. 96: 211–239. *f. 1–9.* Je 1926.

Barnhart, J. H. *Chelone glabra.* Addisonia **11**: 5–6. *pl. 355.* "Mr" 30 Je 1926.
Native of eastern North America.

Barnum, C. C. The flowering of sugar cane in Hawaii. Hawaiian Pl. Rec. **30**: 382–399. *illust.* Jl 1926.

Bartram, E. B. Notes on the genus *Husnotiella* Cardot. Bryologist **29**: 44–46. "Jl"–20 Au 1926.
H. torquescens described as new combination.

Baxter, S. N. Some rare trees and plants. Parks & Recreation **9**: 619–625. *illust.* Jl–Au 1926.
Includes an account of John Bartram.

Bean, R. C. Some plants found in our Maine mountains. Maine Naturalist **6**: 33–37. *illust.* Mr 1926.

Becker, W. Beiträge zur Violenflora Argentiniens. Repert. Spec. Nov. Reg. Veg. **22**: 350–354. 15 Jl 1926.
Several species described as new.

Belling, J. The attractions of the ends of chromosomes in trivalents and quadrivalents. Nature **118**: 227–228. *f. 1.* 14 Au 1926.

Belling, J. On the occurrence of $2n + 1$ and other chromosomal mutants. Nature **117**: 693. *f. 1.* 15 My 1926.

Benoist, R. La foret et les bois de la Guyane francaise. Ann. Soc. Linn. Lyon n.s. **72**: 21–27. 1926.

Berry, E. W. *Cocos* and *Phymatocaryon* in the Pliocene of New Zealand. Am. Jour. Sci. V, **12**: 181–184. *f. 1–8.* S 1926.

Betts, E. M. Heterothallism in *Ascobolus carbonarius.* Am. Jour. Bot. **13:** 427–432. 20 Jl 1926.

Bienfait, J. L. Relation of the manner of failure to the structure of wood under compression parallel to the grain. Jour. Agr. Res. **33:** 183–194. *f. 1–6.* 15 Jl 1926.

Blake, S. F. A new *Stylosanthes* from British Honduras. Proc. Biol. Soc. Wash. **39:** 51–52. 30 Jl 1926.
S. hamata.

Blake, S. F. Note on "Arboloco." Trop. Woods 7: 33–34. 1 S 1926.

Blake, S. F. Notes on *Disterigma.* Jour. Wash. Acad. Sci. **16:** 361–365. 19 Jl 1926.
Several species described as new.

Blakeslee, A. F. Variation, heredity, and environment in relation to evolution. Jour. N. Y. Bot. Gard. **27:** 162–163. Jl 1926.
Abstract of a lecture.

Bogayong, J. R. *Anthracnose* of eggplant. Philipp. Agr. Rev. **18:** 558–559. *pl. 87.* O–D 1925. (Philippine Is. Bur. Agr. Circ. 168.)

Bordeleau, R. La pathologie végétal en France. Sci. Agr. **6:** 396–402. Jl 1926.

Bowen, R. H. Preliminary notes on the structure of plant protoplasm. Science II, **63:** 620–621. 18 Je 1926.

Bower, F. O. 1860–1894–1926. Am. Nat. **60:** 455–478. S–O 1926.
An account of William Bateson.

Boynton, K. R. *Lapeyrousia cruenta.* Addisonia **11:** 11–12. *pl. 358.* "Mr" 30 Je 1926.
Native of South Africa.

Boynton, K. R. *Lycoris squamigera.* Addisonia **11:** 15–16. *pl. 360.* "Mr" 30 Je 1926.
Native of Japan.

Boynton, K. R. *Tecomaria capensis.* Addisonia **11:** 7–8. *pl. 356.* "Mr" 30 Je 1926.
Native of South Africa.

Boynton, K. R. *Thunbergia Gibsoni.* Addisonia **11:** 3–4. *pl. 354.* "Mr" 30 Je 1926.
Native of tropical East Africa.

Bradshaw, R. V. The mosses of Stanford University and vicinity. Bryologist **29:** 33–36. "Jl"–20 Au 1926.

Brentzel, W. E. Loose smut of wheat. No. Dakota Agr. Exp. Sta. Circ. 29: 1–11. *f. 1–6.* F 1926.

Brink, R. A., & Abegg, F. A. Dynamics of the waxy gene in maize. I. The carbohydrate reserves in endosperm and pollen. Genetics **11:** 163–199. *f. 1–9 + pl. 1.* "Mr" 10 Au 1926.

Brink, R. A., MacGillivrary, J. H., & Demerec, M. Effect of the waxy gene in maize pollen,—a reply to criticisms. Genetics **11:** 38–40. "Ja" 16 Jl 1926.

Britton, N. L. *Osmia borinquensis.* Addisonia **11:** 9–10. *pl.* 357. "Mr" 30 Je 1926.
Native of Porto Rico.

Browne, C. A. Sir John Burchmore Harrison. Science II, **63:** 587–589. 11 Je 1926.

Bulger, R. O. Stem rust and the common barberry in South Dakota. So. Dakota Coll. Agr. Ext. Div. Circ. 240: 1–23. *f. 1–13.* Je 1926.

Burret, M. Beiträge zur Kenntnis der Tiliaceen. Notizb. Bot. Gart. Berlin **9:** 592–880. 22 Jl 1926.

Carsner, E. Susceptibility of the bean to the virus of sugar-beet curly-top. Jour. Agr. Res. **33:** 345–348. *f. 1.* 15 Au 1926.

Chardón, C. E. La poda del café. Rev. Agr. Puerto Rico **17:** 7–13. *f. 1–4.* Jl 1926.

Cheney, R. H. Plant arrow-poisons; their sources, preparation, and effects. Jour. N. Y. Bot. Gard. **27:** 174–177. Au 1926.
Abstract of a lecture.

Clara, F. M. Diseases of tobacco (*Nicotiana tabacum* L.) in the Philippines. Philipp. Agr. Rev. **18:** 564–570. *pl. 89–91.* O–D 1925. (Philippine Is. Bur. Agr. Circ. 171.)

Cleland, R. E. Meiosis in the pollen mother cells of *Oenothera biennis* and *Oenothera biennis sulfurea*. Genetics **11**: 127–162. *f. 1–7*. "Mr" 18 Au 1926.

Clute, W. N. The gum plant. Am. Bot. **32**: 93–94. *illust.* Jl 1926.
Grindelia squarrosa.

Coburn, L. H. The gentian family in Maine. Maine Naturalist **5**: 106–110. Mr 1926.

Cockerell, T. D. A. Lamarck's new names in the French edition of Pallas. Torreya **26**: 67–69. 11 Au 1926.

Cockerell, T. D. A. A Miocene *Orontium* (Araceae). Torreya **26**: 69. *illust.* 11 Au 1926.
O. fossile described as new species.

Cook, O. F. A new genus of palms based on *Kentia forsteriana*. Jour. Wash. Acad. Sci. **16**: 392–397. 19 Au 1926.
Denea.

Cook, O. F., & Hubbard, J. W. New species of cotton plants from Sonora and Sinaloa, Mexico. Jour. Wash. Acad. Sci. **16**: 333–339. 19 Je 1926.

Cook, S. F. The toxic action of copper on *Nitella*. Jour. Gen. Physiol. **9**: 735–754. *f. 1–8.* 20 Jl 1926.

Coulter, J. M. Boyce Thompson Institute for Plant Research. Sci. Mo. **23**: 97–106. *illust.* Au 1926.

Coulter, J. M. Boyce Thompson Institute work. Seed World **20^2**: 16–17. 16 Jl 1926.

Coulter, J. M. How the Boyce Thompson Institute is helping the nurseryman. Flor. Exch. **62**: 993, 995. 17 Jl 1926.

Coulter, J. M. Seed research work of the Boyce Thompson Institute. Flor. Exch. **62**: 1067. 24 Jl 1926.

Coville, F. V. Buttermilk as a fertilizer for blueberries. Science II, **64**: 94–96. *illust.* 23 Jl 1926.

Coville, F. V. *Olearia* versus *Shawia*. Jour. Bot. **64**: 193–194. Jl 1926.

Dahlberg, R. Tva *Anemone*-arter *A. silvestris* och *A. pennsyl-*

vanica. Fran Blomstergarden **1**: 60–66. *illust.* "1925" 1926.

Davies, P. A. Effect of high pressure on germination of seeds (*Medicago sativa* and *Melilotus alba*). Jour. Gen. Physiol. **9**: 805–809. 20 Jl 1926.

Davis, B. M. The segregation of *Oenothera nanella-brevistylis* from crosses with *nanella* and with *Lamarckiana.* Genetics **11**: 57–72. "Ja" 16 Jl 1926.

Davis, W. E. The use of catalase as a means of determining the viability of seeds. Proc. An. Meet. Assoc. Off. Seed Analysts of No. Am. 18: 1–12. 1925. (Boyce Thompson Inst. Prof. Paper 2.)

Dearness, J. New or noteworthy fungi—IV. Mycologia **18**: 236–255. 1 S 1926.

Demaree, J. B., & Cole, J. R. Commercial control of pecan scab. U. S. Dept. Agr. Circ. 386: 1–8. Jl 1926.

Dickey, S. S. The table-mountain pine. Nat. Mag. **8**: 38. *illust.* Jl 1926.
Pinus pungens.

Duggar, B. M. How plants behave when diseased. Sci. Mo. **23**: 177–180. Au 1926.

Dunn, S., & Bakke, A. L. Adsorption as a means of determining relative hardiness in the apple. Plant Physiol. **1**: 165–178. Ap 1926.

Dutton, W. C. Concentration of materials and rates of application in the control of apple scab. Michigan Agr. Exp. Sta. Tech. Bull. 76: 1–18. Je 1926.

Edgerton, C. W., Taggart, W. G., & Tims, E. C. The selection of seed cane. Louisiana Agr. Exp. Sta. Bull. 195: 1–18. *f. 1–8.* Jl 1926.

Edmond, J. B. Influence of nutrient supply on earliness of maturity in cabbage. Michigan Agr. Exp. Sta. Tech. Bull. 75: 1–16. Mr 1926.

Ekman, E. L. Botanizing in Haiti. U. S. Naval Med. Bull. 24: 483–497. Jl 1926.

Eyster, W. H. Chromosome VIII in Maize. Science II, **64**: 22. 2 Jl 1926.

Fabre, J. H. The wonder book of plant life. i–xii, 1–410. *f. 1–187.* Phila., Lippincott, 1925.

Fawcett, H. S., & Lee, H. A. Citrus diseases and their control. ed. 1. 1–582. *f. 1–205.* New York, McGraw-Hill, 1926.

Folsom, D., Schultz, E. S., & Bonde, R. Potato degeneration diseases; natural spread and effect upon yield. Maine Agr. Exp. Sta. Bull. 331: 57–112. Mr 1926.

Fraser, W. P. & Scott, G. A. Smut of western rye grass. Phytopathology **16**: 473–477. *f. 1, 2.* 15 Jl 1926.

Freeman, O. M. *Viola primulifolia* in Berkshire County, Massachusetts. Rhodora **28**: 132. 22 Jl 1926.

French, G. H. Some interesting southern Illinois plants. Proc. Illinois S. Acad. Sci. **18**: 208–211. "1925" 1926.

Frenguelli, J. Los estudios diatomologicos en la Argentina. Nuova Notarisia **36**: 305–318. "1925" 1926.

Frost, H. B. Bud variation and chimeras in *Matthiola incana* R. Br. Jour. Agr. Res. **33**: 41–46. *f. 1–3.* 1 Jl 1926.

Gadsby, Mrs. E. J. Meanderings 'mong mosses. Bryologist **29**: 43–44. "Jl"–20 Au 1926.
In Wales, Scottish Highlands, and Lake district of England.

Galloway, B. T. The search in foreign countries for blight-resistant chestnuts and related tree crops. U. S. Dept. Agr. Circ. 383: 1–16. *f. 1–5.* Je 1926.

Gates, F. C. Contributions to the flora of Hancock county, Illinois. Proc. Illinois S. Acad. Sci. **18**: 225–234. "1925" 1926.

Garber, R. J. Size inheritance. Science II, **64**: 17. 2 Jl 1926.

Gilbert, B. E. The adaptation of certain colorimetric methods to the estimation of nitrates, phosphates and potassium in plant solutions. Plant Physiol. **1**: 191–199. Ap 1926.

Gilbert, W. W. An improved method for isolation of *Thielavia basicola.* Phytopathology **16**: 579. 15 Au 1926.

[Gleason, H. A.] El Sr. H. A. Gleason, del jardin botanico de Nueva York hace un estudio ecologico de la isla. Rev. Agr. Puerto Rico **17**: 14–17. Jl 1926.

Godfrey, G. H. Effect of temperature and moisture on nematode root knot. Jour. Agr. Res. **33**: 223–254. *f. 1–15.* 1 Au 1926.

Goldring, W. New Upper Devonian plant material. New York. S. Mus. Bull. 267: 85–87. *illust.* Ap 1926.

Gomez, E. T. "Blight of gabi" (*Phytophthora colocasiae* Rac.) in the Philippines. Philipp. Agr. Rev. **18**: 560–561. *pl. 88.* O–D 1925. (Philippine Is. Bur. Agr. Circ. 169.)

Green, F. The precipitin reaction in relation to grafting. Genetics **11**: 73–82. "Ja" 16 Jl 1926.

Gregory, C. T. Some twig enemies. Nat. Mag. **8**: 84–88. *illust.* Au 1926.

Grier, N. M. Comparative regeneration of spinescence in *Opuntia* and *Agave.* Am. Bot. **32**: 94–96. Jl 1926.

Guillot, F. M. Enfermedades de las aves de corral su diagnostico y su tratamiento. Rev. Agr. Puerto Rico **16**: 285–293. Je 1926.

Hall, R. P., & Powell, W. N. Notes on technique and its associated kinetic elements in euglenoid flagellates. Trans. Am. Micros. Soc. **45**: 256–257. Jl 1926.

Hansford, C. G. The Fusaria of Jamaica. Kew Bull. Misc. Inf. **1926**: 257–288. Jl 1926.

Hardy, F. The water relations of Citrus trees. Trop. Agriculture **3**: 152–153. Jl 1926.

Harms, H. Beiträge zur Kenntnis amerikanischer Cucurbitaceen. II. Repert. Spec. Nov. Reg. Veg. **22**: 339–343. 15 Jl 1926.

Harrison, T. J. Plant physiology in relation to agronomy. Sci. Agr. **6**: 380–382. Jl 1926.

Harshberger, J. W. The desert vegetation of the southwest. Jour. N. Y. Bot. Gard. **27:** 163–164. Jl 1926.
Abstract of a lecture.

Harvey, R. B., & Regeimbal, L. O. A conductivity cell for continuous measurements of respiratory rate. Plant Physiol. **1:** 205–206. *f. 1.* Ap 1926.

Haskin, L. L. Love-apples and nightshade. Nat. Mag. **8:** 33–35. *illust.* Jl 1926.

Heald, F. D., & Sprague, R. A spot-rot of apples in storage caused by *Botrytis.* Phytopathology **16:** 485–488. *f. 1.* 15 Jl 1926.

Hein, I. Changes in plastids in variegated plants. Bull. Torrey Club **53:** 411–418. *pl. 17.* "Je" 10 Jl 1926.

Henderson, L. B. Floral anatomy of several species of *Plantago.* Am. Jour. Bot. **13:** 397–405. *pl. 35.* 20 Jl. 1926.

Henrard, J. T. A critical revision of the genus *Aristida.* Meded. Van Rijks Herb. 54: i–viii, 1–220. *illust.* 15 Je 1926.
Many species described as new.

Henry, A., & McIntyre, M. The swamp cypresses, *Glyptostrobus* of China, and *Taxodium* of America, with notes on allied genera. Proc. Roy. Irish Acad. **37B:** 90–116. *pl. 1–8.* 19 My 1926.

Hesler, L. R. Peach disease conditions in Ohio. Ohio Agr. Exp. Sta. Bi-Mo. Bull. **11:** 110–114. My-Je 1926.

Hitchcock, A. S. *Eragrostis hypnoides* and *E. reptans.* Rhodora **28:** 113–115. 22 Jl 1926.

Hofmann, F. W. Hybrid vigor in cow peas. Jour. Hered. **17:** 209–211. *f. 1, 2.* 3 Au 1926.

Hollick, A. A historical review of the study of fossil plants. Jour. N. Y. Bot. Gard. **27:** 177–180. Au 1926.
Abstract of a lecture.

Holm, T. The bulbiferous form of *Luzula multiflora.* Rhodora **28:** 133–138. *f. 1–3.* "Au" 8 S 1926.

Holm, T. *Saururus cernuus* L. a morphological study. Am. Jour. Sci. V, **12**: 162–168. *f. 1–5.* Au 1926.

Howitt, J. E., & Evans, W. G. Preliminary report of some observations on ascospore discharge and dispersal of conidia of *Venturia inaequalis* (Cooke) Winter. Phytopathology **16**: 559–563. 15 Au 1926.

Howland, R. S. Why not bamboo? Am. For. & For. Life **32**: 461–463; 512. *illust.* Au 1926.

Hutchins, L. M. Studies on the oxygen-supplying power of the soil together with quantitative observations on the oxygen-supplying power requisite for seed germination. Plant Physiol. **1**: 95–150. *f. 1–19.* April 1926.

Hutchinson, W. I. The devil's pitchfork. Nat. Mag. 8: 56. *illust.* Jl 1926.

An incense cedar at the junction of Bubbs Creek and fork of Kings River in the Sequoia National Forest.

Jenkins, M. T. A second gene producing golden plant color in maize. Am. Nat. **60**: 484–488. S–O 1926.

Jensen, J. Variations in colors of flowers. Science II, **64**: 120. 30 Jl 1926.

Johnson, J., Slagg, C. M., & Murwin, H. F. The brown root rot of tobacco and other plants. U. S. Dept. Agr. Bull. 1410: 1–30. *f. 1–20.* Jl 1926.

Jones, F. R. Resistance of peas to rootrot. Phytopathology **16**: 459–465. 15 Jl 1926.

Jones, J. S., & Mitchell, G. A. The cause and control of yellow berry in Turkey wheat grown under dry-farming conditions. Jour. Agr. Res. **33**: 281–292. *f. 1–8.* 1 Au 1926.

Jones, J. W. Germination of rice seeds as affected by temperature, fungicides, and age. Jour. Am. Soc. Agron. **18**: 576–592. Jl 1926.

Jordahn, A. C. Queen's wreath—one of Florida's lovely vines. Gard. Chron. Am. **30**: 171. Je 1926.

Petraea volubilis.

Juliano, J. B. Origin, development and nature of the stony layer of the coconut (*Cocos nucifera* Linnaeus). Philipp. Jour. Sci. **30**: 187–200. *pl. 1–3.* Je 1926.

Jurica, H. S. Opportunities for field study in the Chicago area. Proc. Illinois Acad. Sci. **18**: 184–192. *illust.* "1925" 1926.

Karling, J. S. Nuclear and cell division in *Nitella* and *Chara.* Bull. Torrey Club **53**: 319–380. *f. 1–6 + pl. 10–13.* "Je" 10 Jl 1926.

Kendall, A. C. Under the ferns. Bryologist **29**: 46–47. Jl 1926.

Killip, E. P. *Tetrastylis*, a genus of Passifloraceae. Jour. Wash. Acad. Sci. **16**: 365–369. 19 Jl 1926.

T. lobata, described as new species.

Klages, K. H. Metrical attributes and the physiology of hardy varieties of winter wheat. Jour. Am. Soc. Agron. **18**: 529–566. *f. 1–8.* Jl 1926.

Krumbhaar, G. D. *Euphrasia Oakesii* in Hamilton Inlet, Labrador. Rhodora **28**: 131–132. 22 Jl 1926.

Lacroix, D. S. Cranberry flower-bud investigations. Jour. Agr. Res. **33**: 355–363. *f. 1–4.* 15 Au 1926.

Lampman, B. H. Plants that catch live prey. Nat. Mag. **8**: 110. *illust.* Au 1926.

Leach, J. G., & Gilbert, H. C. Diseases of head lettuce in Minnesota. Minnesota Univ. Agr. Ext. Div. Spec. Bull. 106: 1–10. *illust.* Mr 1926.

Lehman, S. G., & Wolf, F. A. *Pythium* root rot of soy bean. Jour. Agr. Res. **33**: 375–380. *f. 1, 2.* 15 Au 1926.

Lehman, S. G., & Wolf, F. A. Soy-bean *Anthracnose.* Jour. Agr. Res. **33**: 381–390. *f. 1–3.* 15 Au 1926.

Leighty, C. E., Sando, W. J., & Taylor, J. W. Intergeneric hybrids in *Aegilops*, *Triticum* and *Secale.* Jour. Agr. Res. **33**: 101–141. *f. 1–18.* 16 Jl 1926.

Leon, H. Excursion botanica a la Costa sur de Baracoa. Mem. Soc. Cubana Hist. Nat. "Felipe Poey" **7**: 20–40. *pl. 1, 2.* 1926.

Leukel, R. W., Dickson, J. G., & Johnson, A. G. Seed treatment experiments for controlling stripe disease of barley. Phytopathology **16:** 565–576. 15 Au 1926.

Lewis, F. J. The vegetation and retrogressive changes of peat areas ("muskegs") in central Alberta. Jour. Ecology **14:** 317–341. *f. 1–6 + pl. 6–10.* Au 1926.

Linford, M. B. Black-leaf of peas caused by *Fusicladium pisicola* n.sp. Phytopathology **16:** 549–559. *pl. 26, 27.* 15 Au 1926.

Loesener, T. Beiträge zur Kenntnis der Flora von Central-Amerika (einschliesslich Mexiko) III. Bot. Jahr. **60:** 345–374. 1 Au 1926.

Lofthouse, T. A. Plant hunting in the Sierra Nevada. Garden Illust. **48:** 310–311; 328–329; 361–362; 390–391; 598–599; 614–615. *illust.* 29 My; 5, 19 Je; 3 Jl; 2, 9, O 1926.

Lohnis, F., & Leonard, L. T. Inoculation of legumes and non-legumes with nitrogen-fixing and other bacteria. U. S. Dept. Agr. Farmers Bull. 1496: 1–28. *f. 1–19.* Au 1926.

Lomanitz, S. A study of physiological balance for alfalfa in solution cultures. Soil Sci. **22:** 97–106. *f. 1–5 + pl. 1.* Au 1926.

Lombard, L. H. The wall-flower. Am. Bot. **32:** 109–110. Jl 1926.

Longyear, B. O. The nature of decay in wood. Colorado Agr. Exp. Sta. Bull. 307: 1–58. *f. 1–5.* Mr 1926.

Loomis, W. E. A study of the clearing of alcoholic plant extracts. Plant Physiol. **1:** 179–189. Ap 1926.

Lyon, H. L. Exotic trees in Hawaii. Hawaiian Pl. Rec. **30:** 349–353. *illust.* Jl 1926.

McCool, M. M., & Romaine, J. P. Some soil and plant relationships. Soil Sci. **22:** 31–34. Jl 1926.

MacDougal, D. T. Growth and permeability of century-old cells. Am. Nat. **60:** 393–415. *f. 1–5.* S–O 1926.

McDougall, W. B. Lichens and symbiosis. Proc. Illinois Acad. Sci. **18:** 161–164. "1925" 1926.

MacFadden, F. A. A trip to the new Denver glacier. Bryologist **29:** 40–42. "Jl" 20 Au 1926.

McLarty, H. R. Witches' broom of potatoes. Sci. Agr. **6:** 395. *illust.* Jl 1926.

Mangelsdorf, P. C. The genetics and morphology of some endosperm characters in Maize. Connecticut Agr. Exp. Sta. Bull. 279: 513–614. *f. 51–76 + pl. 21–26.* Je 1926.

Maria, H. A. Las Ranunculaceaes Colombianas. Bol. Soc. Colombiana Ci. Nat. **15:** 60–75. Ap–My 1926.

Marquez, S. L. Fiji disease of sugar cane. Philipp. Agr. Rev. **18:** 573–574. O–D 1925. (Philippine Is. Bur. Agr. Circ. 174.)

Marquez, S. L. Leaf blight of corn (caused by *Helminthosporium inconspicuum* Cke. et Ell.). Philipp. Agr. Rev. **18:** 571–572. O–D 1925. (Philippine Is. Bur. Agr. Circ. 173.)

Marquez, S. L. Sugar-cane smut (caused by *Ustilago sacchari* Rabenhorst). Philipp. Agr. Rev. **18:** 562–563. O–D 1925. (Philippine Is. Bur. Agr. Circ. 170.)

Martin, W. H. Apple scab studies in 1925. Proc. New Jersey S. Hort. Soc. **51:** 71–85. "1925" 1926.

Massey, L. M. *Fusarium* rot of *Gladiolus* corms. Phytopathology **16:** 509–524. *f. 1–3 + pl. 25.* 15 Au 1926.

Melhus, I. E., Erwin, A. T., & Haltern, F. van. Cabbage yellows, caused by *Fusarium conglutinans*, in Iowa. Iowa Agr. Exp. Sta. Bull. 235: 187–216. *illust.* Je 1926.

Mellor, E. M. The countries our drugs come from. XVIII. Barbados, the Leeward islands, the Windward islands. Pharm. Jour. **116** (IV, **62**): 662–664. 26 Je 1926.

Merrill, E. D. An efficient and economical herbarium paste. Torreya **26:** 63–65. 11 Au 1926.

Merrill, E. D. Hugh Cuming's letters to Sir William J. Hooker. Philipp. Jour. Sci. **30:** 153-186. *pl. 1.* Je 1926.

Merrill, G. K. Dooryard lichenology. Maine Nat. **6:** 29–32. Mr 1926.

Miller, J. W. Eight generations of selection within a clone of *Helminthosporium sativum.* Am. Nat. **60:** 340–343. *f. 1.* Jl–Au 1926.

Mol, W. E. de. Heteroploidy and somatic variation in the Dutch flowering bulbs. Am. Nat. **60:** 334–339. Jl–Au 1926.

Molz, F. J., A study of suction force by the simplified method. I. Effect of external factors. II. Periodic variations and the influence of habitat. Am. Jour. Bot. **13:** 433–463; 465–501. *f. 1–3.* 20 Jl; 15 O 1926.

Monteith, J. [Jr.] The brown-patch disease of turf; its nature and control. Bull. U. S. Golf Assoc. Green Sect. **6:** 127–142. *illust.* Je 1926.

Moore, S. A new species of *Flourensia* from Argentina. Jour. Bot. **64:** 191–192. Jl 1926.
F. grindelioides.

Morris, V. H., & Welton, F. A. The importance of clearing the hydrolyzed solution in the determination of acid-hydrolyzable carbohydrates in green plant tissue. Jour. Agr. Res. **33:** 195–199. 15 Jl 1926.

Murrill, W. A. From Rio to Petropolis. Torreya **26:** 61–62. 11 Au 1926.

Newhall, A. G. The importance of controlling celery blight in the seedbed. Phytopathology **16:** 467–472. *f. 1.* 15 Jl 1926.

Nixon, E. L. Fire blight. Pennsylvania Agr. Exp. Sta. Bull. 203: 1–22. *f. 1–16.* Je 1926.

Noe, A. C. The fossil flora of northern Illinois. Proc. Illinois Acad. Sci. **18:** 206–207. "1925" 1926.

Norton, A. H. Edward Blanchard Chamberlain. Maine Nat. **5:** 100–105. *port.* 1926.
Born 24 Jl 1878. Died 2 F 1925.

Noyes, J. Extension of Missouri Botanical Garden to Gray

Summit. Parks and Recreation **9:** 595–598. *illust.* Jl–Au 1926.

Osborn, H. F. The problem of the origin of species as it appeared to Darwin in 1859 and as it appears to us today. Nature **118:** 270–273. 21 Au 1926.

Patel, M. K. An improved method of isolating *Pseudomonas tumefaciens* Sm. and Town. Phytopathology **16:** 577. 15 Au 1926.

Peattie, D. C. Lamarck; a neglected genius. Nat. Mag. **8:** 109–110. *illust.* Au 1926.

Peattie, D. C. The tramp with the golden crown. Nat. Mag. **8:** 23–24. *illust.* Jl 1926.
The dandelion.

Peattie, D. C. What is a common name? Am. Bot. **32:** 111–113. Jl 1926.

Pellett, F. C. A plant new to the United States. Science II, **63:** 637. 25 Je 1926.
Zygophyllum fabago.

Pemberton, C. C. Twining firs. Are the lordly firs degenerating into mere climbers? Am. For. & For. Life **32:** 521–523. *illust.* S 1926.

Pennell, F. W. *Allophyton mexicanum.* Addisonia **11:** 13–14. *pl. 359.* "Mr" 30 Je 1926.
Native of eastern Mexico.

Petery, W. von. Investigation in regard to weed seeds found among the seeds of Argentina, with reference to their origin and distribution in the producing district of Argentina. Int. Rev. Sci. & Prac. Agr. n.s. **3:** 1163–1171. O–D 1925.

Phillips, J. Biology of the flowers, fruits and young regeneration of *Olinia cymosa* Thunb. ("Hard pear"). Ecology **7:** 338–350. "Jl" 4 Au 1926.

Porter, R. H. A preliminary report of surveys for plant diseases in east China. U. S. Dept. Agr. Pl. Dis. Rept. Suppl. 46: 153–166. *illust.* 1 Je 1926.

Prescott, A. Spring flowers. Am. Bot. **32:** 105–107. Jl 1926.

Priest, S. B. The Indian pipe. Am. Bot. **32:** 110–111. Jl 1926.
Monotropa uniflora.

Ranker, E. R. Some physiological considerations of the "Delicious" apple with special reference to the problem of alternate bearing. Am. Jour. Bot. **13:** 406–426. 20 Jl 1926.

Record, S. J. The Editor visits Central America. Trop. Woods. 7: 1–3. 1 S 1926.

Record, S. J., & Kuylen, H. Trees of the lower Rio Motagua valley, Guatemala. Trop. Woods 7: 10–29. 1 S 1926.

Rendle, A. B. The need for precision in botanical terminology. Nature **118:** 103–104. 17 Jl 1926.

Reynolds, E. S. Nutritional studies on *Fusarium lini.* Plant Physiol. **1:** 151–164. *f. 1–3.* Ap 1926.

Roberts, R. H. Apple physiology; growth, composition, and fruiting responses in apple trees. Wisconsin Agr. Exp. Sta. Res. Bull. 68: 1–72. *f. 1–24.* My 1926.

Roldan, E. F. Bacterial wilt of marigold of Amarilla. Philipp. Agr. **15:** 37–40. *illust.* Je 1926.

Rosa, J. T. Mutations in the sweet potato. Jour. Hered. **17:** 167–168. *f. 3.* "My" 7 Jl 1926.

Rose, J. N. *Graptopetalum Bartramii.* Addisonia **11:** 1–2 *pl. 353.* "Mr" 30 Je 1926.
Native of Arizona.

Rosen, H. R. Morphological notes together with some ultrafiltration experiments on the crown-gall pathogene, *Bacterium tumefaciens.* Mycologia **18:** 193–205. *pl. 24, 25.* 1 S 1926.

Rusby, H. H. Tropical American plants at home—V. The climbing Bignoniads. Jour. N. Y. Bot. Gard. **27:** 169–173. Au 1926.

Sanford, G. B. Some factors affecting the pathogenicity of *Actinomyces scabies.* Phytopathology **16:** 525–547. *f. 1–3.* 15 Au 1926.

Sax, K. Quantitative inheritance in *Phaseolus*. Jour. Agr. Res. **33**: 349–354. 15 Au 1926.

Schaffner, J. H. The change of opposite to alternate phyllotaxy and repeated rejuvenations in hemp by means of changed photoperiodicity. Ecology **7**: 315–325. *f. 1.* "Jl" 4 Au 1926.

Schlechter, R. Das System der Orchidaceen. Notizb. Bot. Gart. Berlin **9**: 563–591. 22 Jl 1926.

Schmoe, F. How nature rotates her tree crops. Am. For. & For. Life **32**: 472–473. *illust.* Au 1926.

Scott, F. M. Notes on the flora of the Miocene of the Tesla region, California. Bull. Torrey Club **53**: 403–410. *pl. 16.* "Je" 10 Jl 1926.

Sears, P. B., & Metcalf, E. The behavior of pollen starch in a *Geranium* and its bud sport. Jour. Genetics **17**: 33–42. *f. 1–3.* 20 Au 1926.

Semmens, E. S. Some further notes on the hydrolysis of starch grains under polarized light. Plant Physiol. **1**: 201–204. *pl. 8.* Ap 1926.

Serrano, F. B. Banana diseases in the Philippines. Philipp. Agr. Rev. **18**: 578–582. *pl. 93–95.* O–D 1925. (Philippine Is. Bur. Agr. Circ. 176.)

Sheldon, H. H. Polarized light and plants. Preliminary research traces an apparent connection between moonlight and plant growth. Sci. Am. **135**: 10–11. *illust.* Jl 1926.

Shull, C. A. Citation of literature. Plant Physiol. **1**: 206–207. Ap 1926.

Shull, C. A. Phosphorus and the early maturity of plants. Proc. Illinois Acad. Sci. **18**: 165–171. *f. 1.* "1925" 1926.

Small, J. K. A new catchfly from the southeastern states. Torreya **26**: 65–67. *illust.* 11 Au 1926.
Silene Wherryi.

Smith, E. F., & Quirk, A. J. A *Begonia* immune to crowngall; with observations on other immune or semi-immune plants. Phytopathology **16**: 491–508. *f. 1–5.* 15 Au 1926.

Smith, G. M. The plankton algae of the Okoboji region Trans. Am. Micr. Soc. **45**: 156–233. *illust.* Jl 1926.

Stadler, L. J. The variability of crossing over in Maize. Genetics **11**: 1–37. *f. 1–6.* "Ja" 16 Jl 1926.

Standley, P. C. New species of trees collected in Guatemala and British Honduras by Samuel J. Record. Trop Woods **7**: 4–9. 1 S 1926.

Stanton, T. R., Coffman, F. A., & Wiebe, G. A. Fatuoid or false wild forms in Fulghum and other oat varieties. Jour. Hered. **17**: 153–166; 213–226. *f. 1–7.* 7 Jl; 3 Au 1926.

Stevens, N. E. Two species of *Physalospora* on *Citrus* and other hosts. Mycologia **18**: 206–217. *f. 1, 2.* 1 S 1926.

Stout, A. B. Why are chestnuts self-fruitless? Jour. N. Y. Bot. Gard. **27**: 154–158. *f. 1.* Jl 1926.

Svihla, R. D., & Svihla, A. Notes on *Buxbaumia aphylla* Haller. Bryologist **29**: 36–37. "Jl" 20 Au 1926.

Taylor, N. Notes on the plant life of the DuVal Trail, from Brandon, Vermont to the Long Trail on the Green Mountains. 1–8. Green Mountain Club, 1926.

Tehon, L. R. Outstanding features of the plant disease situation in Illinois during 1924. Proc. Illinois S. Acad. Sci. **18**: 150–160. "1925" 1926.

Tehon, L. R. Three alfalfa diseases new to Illinois. Proc. Illinois S. Acad. Sci. **18**: 203–205. "1925" 1926.

Peronospora trifoliorum, Macrosporium medicaginis and *Pleosphaerulina brisosiana.*

Teodoro, N. G. Coconut diseases and their control. Philipp. Agr. Rev. **18**: 585–592. *pl. 97–101.* O–D 1925. (Philippine Is. Bur. Agr. Circ. 179.)

Teodoro, N. G. Phytopathology; its fundamental principles. Philipp. Agr. Rev. **18**: 325–371. *f. 8–32 + pl. 40–69.* O–D 1925.

Teodoro, N. G. Rubber tree diseases and their control. Philipp. Agr. Rev. **19**: 63–73. Ja–Ap 1926.

Teodoro, N. G., & Otanes, F. G. Philippine literature index of plant pests and diseases. I. Philipp. Agr. Rev. **18:** 593–602. O–D 1925.

Theriot, I. Mexican mosses collected by Brother Arsène Brouard. Smithsonian Misc. Coll. **78**^{2}**:** 1–29. *f. 1–10.* 15 Je 1926.

Species in *Aongstroemia, Campylopus, Fissidens, Bryum* and *Prionodon,* described as new.

Thompson, W. P. Chromosome behavior in triploid wheat hybrids. Jour. Genetics **17:** 43–48. *f. 1–8.* 20 Au 1926.

Tisdale, W. B., & Kelley, J. G. A *Phytophthora* disease of tobacco. Florida Agr. Exp. Sta. Bull. 179: 159–219. *f. 88–114.* My 1926.

Tisdale, W. H. Copper carbonate prevents bunt (stinking smut) of wheat. U. S. Dept. Agr. Circ. 394: 1–10. *f. 1–6.* Jl 1926.

Tottingham, W. E., Lepkovsky, S., Schulz, E. R., & Link, K. P. Climatic effects in the metabolism of the sugar beet. Jour. Agr. Res. **33:** 59–76. *f. 1–9.* 1 Jl 1926.

Trelease, W. *Agave Ekmani,* n. sp. Repert. Spec. Nov. Reg. Veg. **22:** 374. 15 Jl 1926.

From Cuba.

Turgano, H. M. Leaf crystals in *Ficus* and other genera. Philipp. Agr. **15:** 41–48. Je 1926.

Urban, I. Sertum antillanum. III. Repert. Spec. Nov. Reg. Veg. **14:** 331–343. 30 Je 1916; IV. **15:** 98–112. 31 D 1917; V. **15:** 156–171. 31 My 1918; VI. **15:** 305–323. 31 D 1918; VII. **15:** 397–415. 31 Mr 1919.

Many species and combinations from the West Indies, described as new.

Urban, I. Sertum antillanum. IX. Repert. Spec. Nov. Reg. Veg. **16:** 132–151. 15 N 1919.

Many species and combinations from the West Indies, described as new.

Urban, I. Sertum antillanum. XII. Repert. Spec. Nov. Reg. Veg. **17:** 156–170. 1921; XIII. **17:** 402–408. 1921; XIV. **18:** 17–26. 31 My 1922; XV. **18:** 113–122. 15 Au 1922; XVI. **18:** 187–199. 15 O 1922; XVII. **18:** 363–375. 31 D

1922; XVIII. **19:** 1–9. 1 Mr 1923; XIX. **19:** 298–308. 20 F 1924.

Many species and combinations from the West Indies, described as new.

Urban, I. Sertum antillanum. XXI. Repert. Spec. Nov. Reg. Veg. **20:** 337–352. 31 D 1924; XXII. **21:** 53–75. 25 Mr 1925; XXIII. **21:** 213–230. *pl. 1.* 20 Jl 1925; XXIV. **22:** 35–48. 30 N 1925; XXV. **22:** 83–93. 31 D 1925; XXVI. **22:** 222–241. 15 Je 1926; XXVII. **22:** 355–372. 15 Jl 1926.

Many species and combinations from the West Indies, described as new.

VanName, W. G. Redwood Mountain Sequoia grove. Nat. Mag. **8:** 107–108. *illust.* Au 1926.

Walker, B. Amateurs and science. Am. Bot. **32:** 114–115. Jl 1926.

Walker, M. N. A comparative study of the mosaic diseases of cucumber, tomato, and *Physalis.* Phytopathology **16:** 431–458. 15 Jl 1926.

Wallace, R. H. The production of intumescences upon apple twigs by ethylene gas. Bull. Torrey Club **53:** 385–402. *pl. 14–15.* "Je" 10 Jl 1926.

Waterman, W. G. Ecological problems from the sphagnum bogs of Illinois. Ecology **7:** 255–272. *f. 1–5.* "Jl" 4 Au 1926.

Weatherby, C. A. A new North American variety of *Cystopteris fragilis.* Rhodora **28:** 129–131. 22 Jl 1926.

Weatherby, C. A. On *Solidago rigida* L., and the application of old botanical names. Rhodora **28:** 138–145. "Au" 8 S 1926.

Weatherwax, P. Persistence of the antipodal tissue in the development of the seed of Maize. Bull. Torrey Club **53:** 381–384. *f. 1–6.* "Je" 10 Jl 1926.

Weedon, A. G. Some Florida fungi. Mycologia **18:** 218–223. *f. 1, 2 + pl. 26.* 1 S 1926.

Two genera, *Exophoma* and *Macrophomopsis*, and several species, described as new.

Weller, D. M. Progress report of sugar cane pollen studies. Hawaiian Pl. Rec. **30:** 400–414. *illust.* Jl 1926.

Wherry, E. T., & Buchanan, R. Composition of the ash of Spanish-moss. Ecology **7**: 303–306. "Jl" 4 Au 1926.

Whetzel, H. H. North American species of *Sclerotinia*—I. Mycologia. **18**: 224–235. *f. 1 + pl. 27–29.* 1 S 1926.

White, O. E. The forests of the Rio Beni Basin of Bolivia. Cornell For. **6**: 16–20. My 1926.

Williams, R. S. *Isothecium occidentale* (Sull. & Lesq.) comb. nov. Bryologist **29**: 48. "Jl" 20 Au 1926.
Hypnum occidentale Sull. & Lesq.

Williams, R. S. Peruvian mosses. Bryologist **29**: 37–38. *pl. 3.* "Jl" 20 Au 1926.
Hygrodicranum Herrerai, described as new species.

Wilson, O. The tree that gives the chocolate. Nat. Mag. **8**: 177–179. *illust.* S 1926.

Wimmer, F. E. Lobelioideae. III. Repert. Spec. Nov. Reg. Veg. **22**: 193–218. *pl. 31–33.* 15 Je 1926.

Wodehouse, R. P. Morphology of pollen grains in relation to plant classification. Jour. N. Y. Bot. Gard. **27**: 145–154. *f. 1–13.* Jl 1926.

Wolf, F. A. Leaf scorch disease of strawberries. No. Carolina Agr. Exp. Sta. Tech. Bull. 28: 1–15. *pl. 1–7.* Ap 1926.

Wolf, F. A., & Lehman, S. G. Brown-spot disease of soy bean. Jour. Agr. Res. **33**: 365–374. *f. 1–9.* 15 Au 1926.

Wolf, F. A., & Lehman, S. G. Diseases of soy beans which occur both in North Carolina and the Orient. Jour. Agr. Res. **33**: 391–396. 15 Au 1926.

Woodruff, L. L. The versatile Sir John Hill, M.D. Am. Nat. **60**: 417–442. *port.* S–O 1926.

Yampolsky, C. The new preformationist doctrine. Genetica **7**: 507–516. 1925.

Yoder, P. A. Rare cases of mosaic disease in highly resistant varieties of sugar cane. U. S. Dept. Agr. Circ. 392: 1–7. Jl 1926.

Zahlbruckner, A. Chilenische flechten gesammelt van C. Skottsberg. Act. Hort. Gothenburg **2**: 1–26. 1926.

Zeller, S. M. Cankers of apple and pear in Oregon and their control. Oregon Agr. Exp. Sta. Circ. 73: 1–29. *f. 1–28.* Ap 1926.

Zeller, S. M. Observations on infections of apple and prune roots by *Armillaria mellea* Vahl. Phytopathology **16**: 479–484. *f. 1–3.* 15 Jl 1926.

The x-bodies in the cells of dahlia plants affected with mosaic disease and dwarf

BESSIE GOLDSTEIN

(WITH TWO TEXT FIGURES AND PLATES 18–20)

A preliminary study of the diseased dahlia plants in and about New York City indicates the existence of a group of diseases which closely resembles that group of the virus diseases loosely characterized as the degeneration diseases of potatoes. I have studied cytologically thus far two of these disease types which I characterize as 'dwarf' and 'mosaic.' 'Dwarf' dahlia plants are usually less than a foot in height, instead of the usual four feet or more. The leaves are small, though not deformed or blotched. 'Mosaic' diseased plants, so far as I have observed, are not markedly dwarfed, but are usually several feet in height, and show distinct mottling in the form of dark green patches, which may or may not be markedly bullate on the light green portions of the young leaves. Such leaves are often distorted and malformed. When flowers occur, they are often small and asymmetrical. The fact that dahlias are propagated by fleshy roots in which the causal agent may pass through the resting condition of the plant to become evident or active again in the new dahlia shoots suggests another point of similarity of these diseases with those of the potato.

I have been unable thus far to find any detailed description of a virus disease of dahlias. Eckerson (1926) mentions the mosaic disease of dahlias, and Kunkel (1926) states that the dwarf disease of dahlias is distinctly different from yellows, and not caused by virulent leafhoppers carrying the causal agent of aster yellows. A mosaic diseased condition of the dahlias at the New York Botanical Garden has been reported as possibly due to the presence of great numbers of leafhoppers.[1] Dudley and Wilson (1921), in the course of their experiments with the potato leafhoppers as the causal agent producing leafhopper-burn of

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[1] The Scientific Directors. A report on scientific research. 23 p. The New York Botanical Garden: New York. 1925.

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potatoes, found that placing nymphs of these insects upon a dahlia plant caused it to become diseased within seven days, and finally blacken and die within twenty days. A plant under a cage free from the insects remained healthy. They suggest that the leafhoppers introduce either a toxin or a disease agent that travels down through the leaf from the regions showing the hopper-burn or yellow margined leaves (the mechanical effects of the insects themselves). The toxin or causal agent evidently causes the plants to blacken (in the case of potato) and die. This seems quite probable to me. It may very well be that the insects introduce a virus into the dahlia plants, which does not in most cases get hold of the dahlia plants in the field during the first season. The virus multiplies within the tissues upon its first introduction, and then recedes to the roots, coming up with the new shoots the next season, and perhaps several seasons thereafter. The virus is finally vigorous or plentiful enough to kill the plant. With each planting of the roots each season, the virus produces a successive series of degenerative effects, which culminate in extreme dwarfing, and the final discarding of the roots for future planting.

Cytological study of the growing points of such plants shows that the intracellular bodies associated with tobacco (Iwanowski, 1903; Palm, 1922; Goldstein, 1924, 1926; Rawlins and Johnson, 1925), with corn mosaic (Kunkel, 1921), *Hippeastrum mosaic* (Kunkel, 1922), the wheat rosette disease (McKinney, Eckerson, and Webb, 1923), and the Fiji disease of sugar cane (McWhorter, 1922, Kunkél, 1924), are also present here and resemble in many respects those associated with the mosaic disease of tobacco and apple of Sodom (*Solanum aculeatissimum*) which I have previously described (1924, 1926) and referred to as the x-bodies. The mosaic diseased leaves that show mottling are thus far the only ones in which I have found these bodies. The x-bodies found in these plants are notably amoeba-like in appearance. Eckerson (1926) refers to elongated flagellate bodies in dahlia phloem, and 'spore forms' are figured and described as present in growing points and badly mottled leaves. Since the drawings presented were made from crushed living material and their relation to the cells was not known, one cannot be certain that these bodies are the x-bodies.

The x-bodies of diseased dahlia plants are often, as noted, distinctly amoeboid in form, with short blunt pseudopodial extensions arising from the body surface (text fig. 1). The body itself may be drawn out into a single elongated pseudopod-like form, or this projection of the body may be curved back so as to form a superimposed lobe (text fig. 1 and fig. 3). The forms of the bodies as observed in various cells suggest very definitely flowing or moving actions on the part of the bodies. The pseudopods may all occur on one side of the body. Often the body shows evidence of moving forward by a simple elongation in a certain direction (text fig. 1). The bodies may be rounded or oval, or extremely elongated. The elongated ones generally occur in elongated cells, although similar elongated cells in the same row or adjacent rows of cells may contain minute or medium sized rounded or oval bodies. Small cells usually contain small bodies. Large cells, however, may contain one or several small bodies, or one or more large or medium sized bodies, or one or more small bodies and larger bodies.

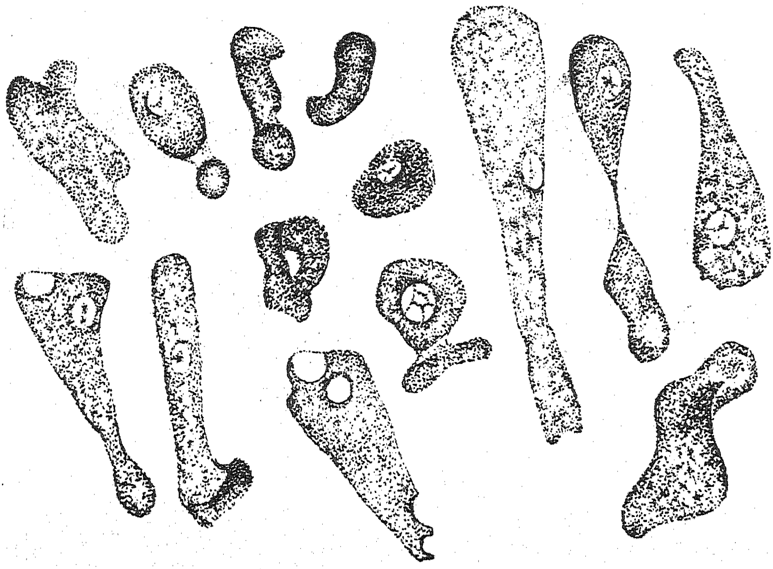

FIG. 1. X-bodies found in the cells of the growing regions of mosaic diseased dahlia plant. Drawn with the aid of the camera lucida, at a magnification of about 2100.

The visible structure of the x-bodies is very much like that of protoplasm (figs. 2 and 12, and text figs. 1 and 2), being finely granular, fibrillar, and alveolar in different regions. They often contain vacuoles (figs. 5 and 14, and text fig. 1). The occurrence of vacuoles on the periphery of these x-bodies (fig. 19) is rather conspicuous, since their occurrence in such a region was never observed in the case of the x-bodies of tobacco. In some cases the limiting membrane is gone, leaving a distinctly rounded indentation on the surface of the body (text fig. 1).

Structures within the material of the body resemble small nuclei (text figs. 1 and 2). A small body with radiating threads is often found lying within a small rounded clear region. I have not found a ring of dense granular material around these structures such as I have found to occur so often in the case of the x-bodies I have described in tobacco plants (1926).

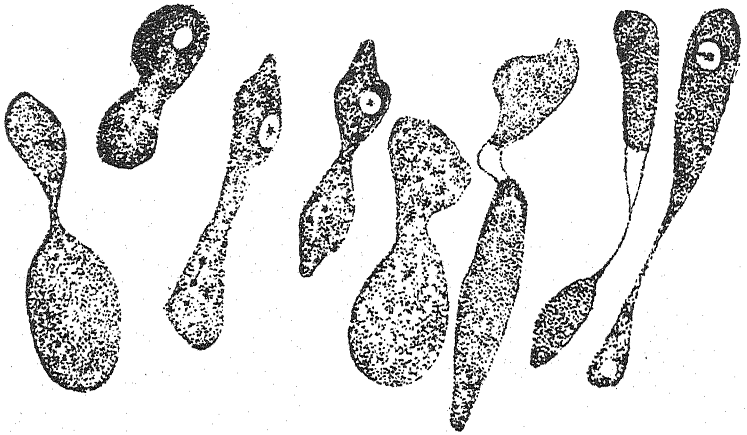

FIG. 2. X-bodies in the cells of the growing regions of dahlia plants affected with mosaic and dwarf. The bodies show evidence of division by constriction.

I have found figures that may be taken as representing every stage in the division of these bodies by constriction, from very slight equatorial narrowing to complete division and separation (text fig. 2). Kunkel (1924) has figured a constricting body in a cell of a gall on a sugar cane plant affected with the Fiji disease. In some cases the content of the body has completely divided and rounded up into separate masses (figs. 6, 7, 8, 9, 11, and 17), while the membrane stretched and constricted between them is still intact. In other cases the membrane is drawn out into a fine thread still connecting the daughter bodies. Sometimes the bodies are small and rounded, and show a very dense content, as if encysted. Such encysted forms have been described by McWhorter (1922) for the amoeboid organisms associated with the Fiji disease of sugar cane. In many cases such bodies show slight light staining pseudopod-like extensions from the dense rounded portion. When such extruded pseudopods are rather elongated, the center of the body shows a large central vacuole within the cyst. McWhorter (1922) has reported that the cysts in the galls of sugar cane germinate to produce a single amoeboid body again.

Often the x-bodies lie in close proximity to the nucleus of the cell, pressed up against it, or partially surrounding it (fig. 15). Such positions of the x-body in close proximity to the nucleus of the cell, pressing upon it or partially enclosing it, have been described and figured by Kunkel (1921) in corn mosaic, and by McKinney, Eckerson, and Webb (1923) in the wheat rosette disease. In one cell the x-body was found within the nucleus—intranuclear, as has been described for various animal virus diseases. One cell shows an x-body in direct contact with the nuclear membrane. The membrane is extended and drawn out into a sharp point, and this point is enveloped by two pseudopodial extensions of the x-body. The x-bodies may be found in the central vacuole, where they often are surrounded by the more or less shrunken mass of the tanniferous network found in the vacuoles in fixed material (fig. 1). Again, they may be found lying within the cytoplasm proper, usually within a thick cytoplasmic bridge crossing the cell space (figs. 12, 14, 16, and 21).

The process of the distribution of these bodies by cell division of the host cell (figs. 4, 18, 20, and 21) is even more marked and conspicuous here than in tobacco, where I (1926) have also figured the various stages in the division of the host cell, with the final distribution of the x-bodies present in the cytoplasm to the two daughter cells. However, in the dahlia I have found a great deal of evidence to show that a more or less definite position is taken up by the several bodies present in the dividing cell with reference to the daughter nuclei and the cell plate forming. In one cell I have found an x-body at each pole of the spindle at the equatorial plate stage (fig. 20). In another cell containing a dividing nucleus in late telophase, the phragmoplast fibers have nearly reached the lateral walls, the daughter nuclei lie close to the young cell plate, and beside each daughter nucleus lies an x-body (fig. 21). A somewhat similar figure is also shown by Kunkel (1924) in a cell of a gall from a sugar cane plant affected with the Fiji disease. A very striking case is that of a cell in which the daughter chromosomes lie on the spindle in an anaphase position half way between the middle of the spindle and the poles. Alongside the spindle are two x-bodies, each on a level with the daughter chromosome groups. Moreover, these bodies show evidence of recent division and separation, in that the elongated portion of each lies on the adjacent surfaces of the bodies. Sometimes more than one body may be left in one cell, or several may be left in one cell, while only one is left in the other.

I have suggested before (1924, 1926) that these bodies may be plastic enough to pass through the pores of anti-bacterial filters. On the margins of my sections I have often found the nuclei, which represent very dense protoplasm, passing through the Tangl lines or plasmodesmen which are invisible under my highest magnifications. Nakahara's (1926) observations of filterable cells of chicken sarcoma, if confirmed, would strengthen the viewpoint that these bodies are also not too large to be the causal agent of the mosaic diseases. The x-bodies are not of the nature of tannin, as shown by the ordinary tannin tests, and by the presence in the same cells of tannin grains, vesicles, and tanniferous networks. They are not distorted conditions of any of the organelles of the cell, since they may be found in cells containing the nucleus of the cells, plastids, tannin deposits, and fine protoplasmic strands crossing the central vacuole, very much as in a normal cell. They are not hypertropied plastids, since they are found even in the cells of the growing point, where plastids have not yet been formed. They are not products of fixation, since they can be found in the cells of material studied in the living condition, as well as in material fixed by various methods of fixation and stained with various stains. They are definite entities in the cells of diseased regions of diseased plants, and show by their appearance in the cells that they cannot be considered simple degeneration products of the host cell, or cell nucleus, because of their very protoplasmic appearance and structure, and the presence within them of internal vacuoles and nuclear-like structures, the presence of peripheral vacuoles, their apparent division by constriction, and their remarkable distribution to the daughter cells on the division of the host cell.

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Literature cited

Dudley, J. E., and Wilson, H. F. Combat potato leafhopper with Bordeaux. Wisconsin Agr. Exp. Sta. Bull. 334: 1–32. *f. 1–17.* 1921.

Eckerson, S. H. An organism of tomato mosaic. Bot. Gaz. **81**: 204–209. *pl. 19–22.* 1926.

Goldstein, B. Cytological study of living cells of tobacco plants affected with mosaic disease. Bull. Torrey Club **51**: 261–273. *pl. 5.* 1924.

————. A cytological study of the leaves and growing points of healthy and mosaic diseased tobacco plants. Bull. Torrey Club **53**: 499–599. *f. 1–4 + pl. 18–29.* 1926.

Iwanowski, D. Über die Mosaickrankheit der Tabakspflanzen. Zeitsch. Pflanzenkr. **13**: 1–41. *pl. 1–3.* 1903.

Kunkel, L. O. A possible causative agent for the mosaic disease of corn. Bull. Exp. Sta. Hawaiian Sugar Planters' Assoc. Bot. Ser. 3: 1–14. *pl. 4–15.* 1921.

————. Amoeboid bodies associated with *Hippeastrum* mosaic. Science II. **55**: 73. 1922.

————. Further studies on the intracellular bodies associated with certain mosaic diseases. Bull. Hawaiian Sugar Planters' Exp. Sta. Bot. Ser. 3: 108–114. *f. 1, 2 + pl. 24.* 1924.

————. Studies on aster yellows. Am. Jour. Bot. **13**: 646–705. *f. 1–4 + pl. 40–44.* 1926.

McKinney, H. H., Eckerson, S. H., and Webb, R. W. The intracellular bodies associated with the rosette disease and a mosaic like leaf mottling of wheat. Jour. Agr. Res. **26**: 605–608. *pl. 1–7.* 1923.

McWhorter, F. P. The nature of the organisms found in Fiji galls of sugar cane. Phillippine Agriculturist **11**: 103–111. *f. 1, 2 + pl. 1, 2.* 1922.

Palm, H. A. Die Mosaikziekte vac de Tabakeen chlamydozoonose? Bull. Deliproefstation te Medan-Sumatra 15: 7–10. 1922.

Explanation of plates

The photographs were made with a Zeiss microscope from stained and sectioned material. The magnification is about 1200 diameters.

PLATE 18

FIG. 1. A parenchyma cell near the growing point. A very dense x-body lies within a tanniferous network in the central vacuole. The nucleus lies against a lateral wall of the cell, and contains a single nucleole.

FIG. 2. A portion of a cell containing a nucleus against the lateral wall, and a large x-body in the central vacuole.

FIG. 3. Portion of a cell containing a somewhat elongated and curved x-body. The nucleus of the cell contains a nucleole.

FIG. 4. A cell containing a division figure at a late telophase stage. The daughter nuclei lie close to the forming cell plate. The phragmoplast is supported within the central vacuole by strands of cytoplasm. Below the figure, an x-body lies in one of these cytoplasmic strands. Above the figure, and close to the daughter nucleus lies a second x-body.

FIG. 5. Two cells in a leaf primordium. The dark small bodies are young plastids. An x-body is present in each cell. One cell also shows the nucleus as a small oval body containing a single dark nucleole lying against the lateral wall.

FIG. 6. A cell containing a constricting x-body. One portion of the x-body is attached to the nuclear membrane, and has pulled it to a point and away from the content of the nucleus.

PLATE 19

FIG. 7. Cells from the midrib of a leaf primordium. The nuclei are deeply stained and lie against the lateral walls. The small oval bodies are young plastids. In one cell the x-body appears quite rounded. In the other cell, the x-body has divided, and the two daughter portions are still enclosed within the unbroken limiting membrane of the original body.

FIG. 8. A cell containing a constricting x-body. The nucleus of the cell lies against the lateral wall. The content of the x-body has completely divided, leaving a clear region within the constricting central region.

FIG. 9. A cell containing a constricting x-body. The content of the body has already moved apart, leaving a clear region within the constricting but still unbroken membrane.

FIG. 10. A young tube cell in which three small x-bodies lie within a cytoplasmic strand above the cell nucleus.

FIG. 11. A similar cell in which the x-body is dividing by constriction.

FIG. 12. A portion of a cell near the growing point. The nucleus is somewhat irregular in form, and contains a single large nucleole. The x-body present is distinctly protoplasmic in appearance and lies within the cytoplasmic threads, which through shrinkage lie away from the bounding walls.

FIG. 13. A group of four cells in a leaf primordium. Each contains an x-body.

FIG. 14. A cell containing a single vacuolate x-body, lying within a thick cytoplasmic bridge crossing the cell vacuole.

PLATE 20

FIG. 15. A cell in which the x-body is partially enveloping the nucleus. The nucleus contains three nucleoles.

FIG. 16. An elongated tube cell containing a single x-body at one end of a protoplasmic strand, and an oval nucleus at the other. The nucleus contains a dark nucleole.

FIG. 17. Three elongated cells below the growing point, each showing the presence of an x-body. In the third cell the x-body is dividing by constriction. The lower portion of the body is very amoeboid in appearance. The upper portion appears smaller than the other half because of the presence of a large pseudopod-like extension upward, which could not be shown in the plane of the picture.

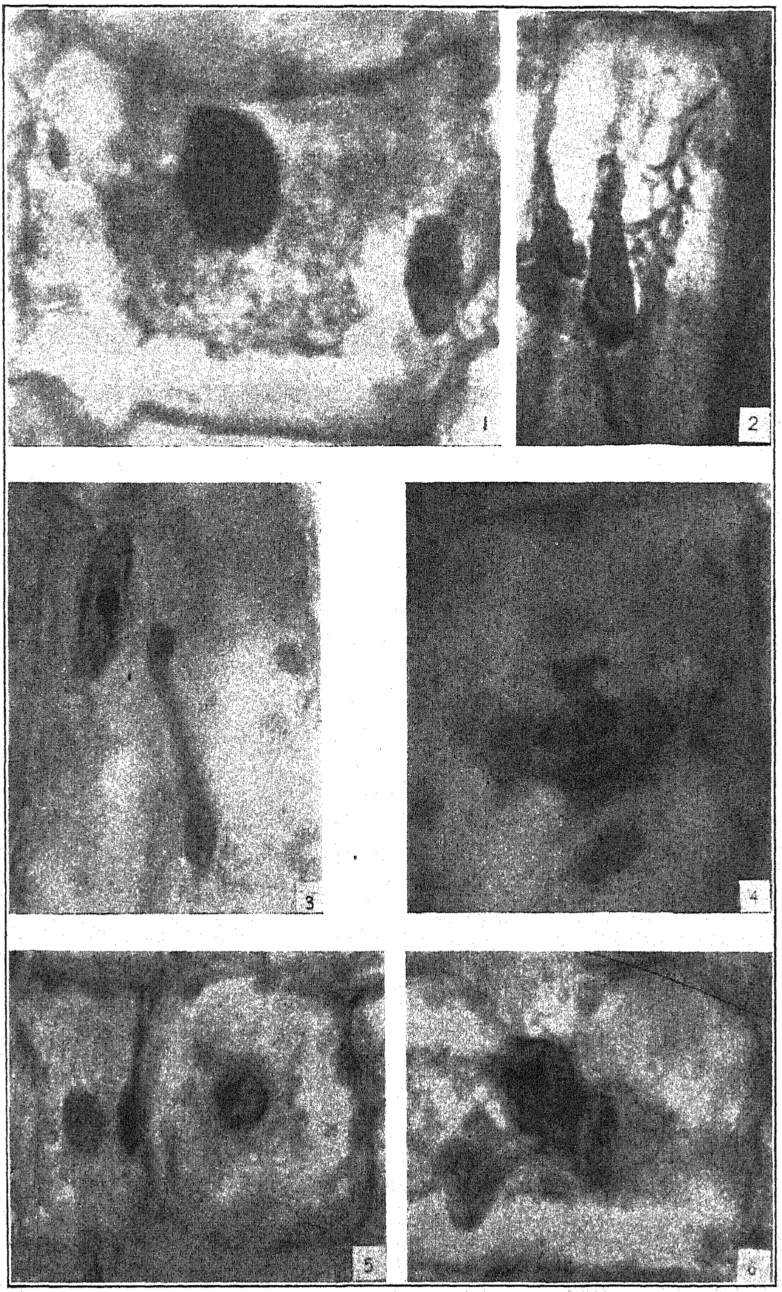
FIG. 18. Two young daughter cells. The daughter nuclei are still pressed up against the young cell plate. An x-body lies in each daughter cell.

FIG. 19. An amoeboid x-body showing the presence of peripheral vacuoles bounded by limiting membranes.

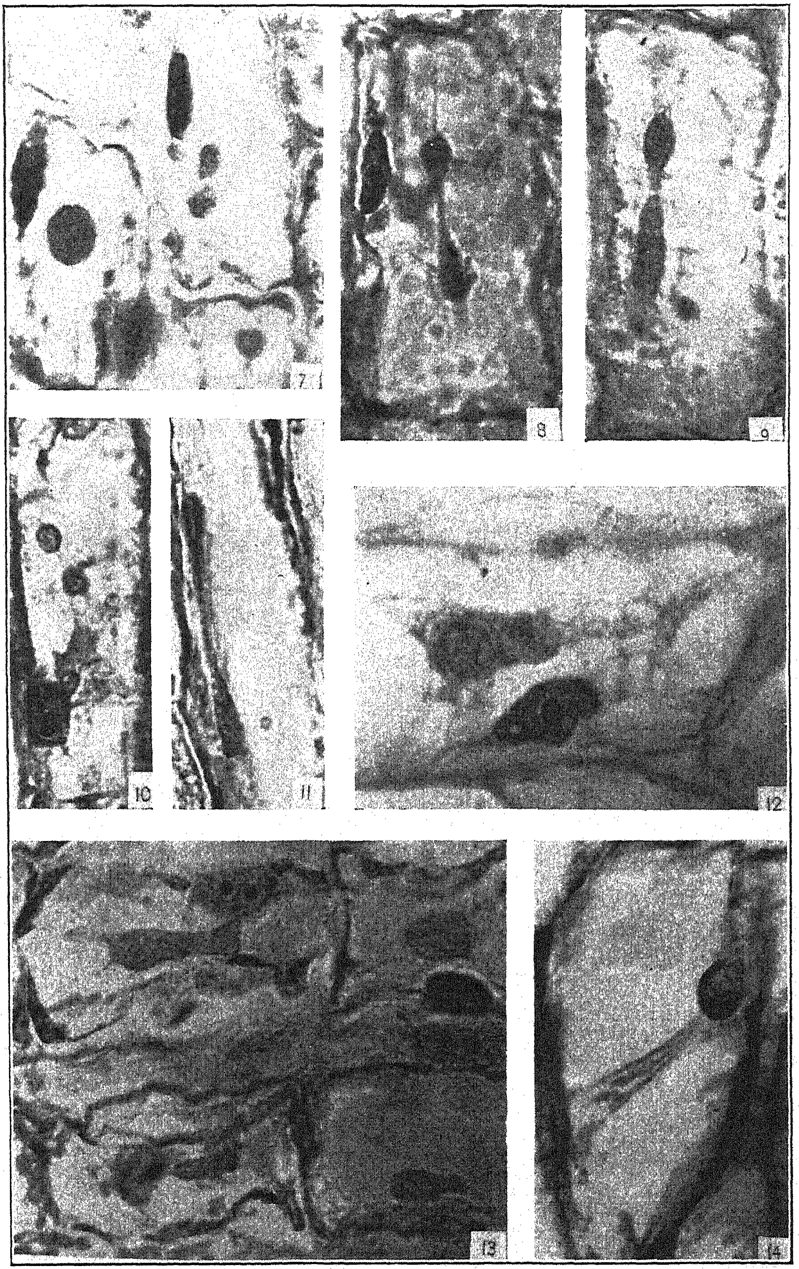
FIG. 20. A cell containing a spindle figure at the equatorial plate stage. An x-body lies near each pole of the spindle.

FIG. 21. Two groups of daughter cells. Each daughter cell contains a nucleus, and an x-body within the protoplasmic sheath against the young cell plates.

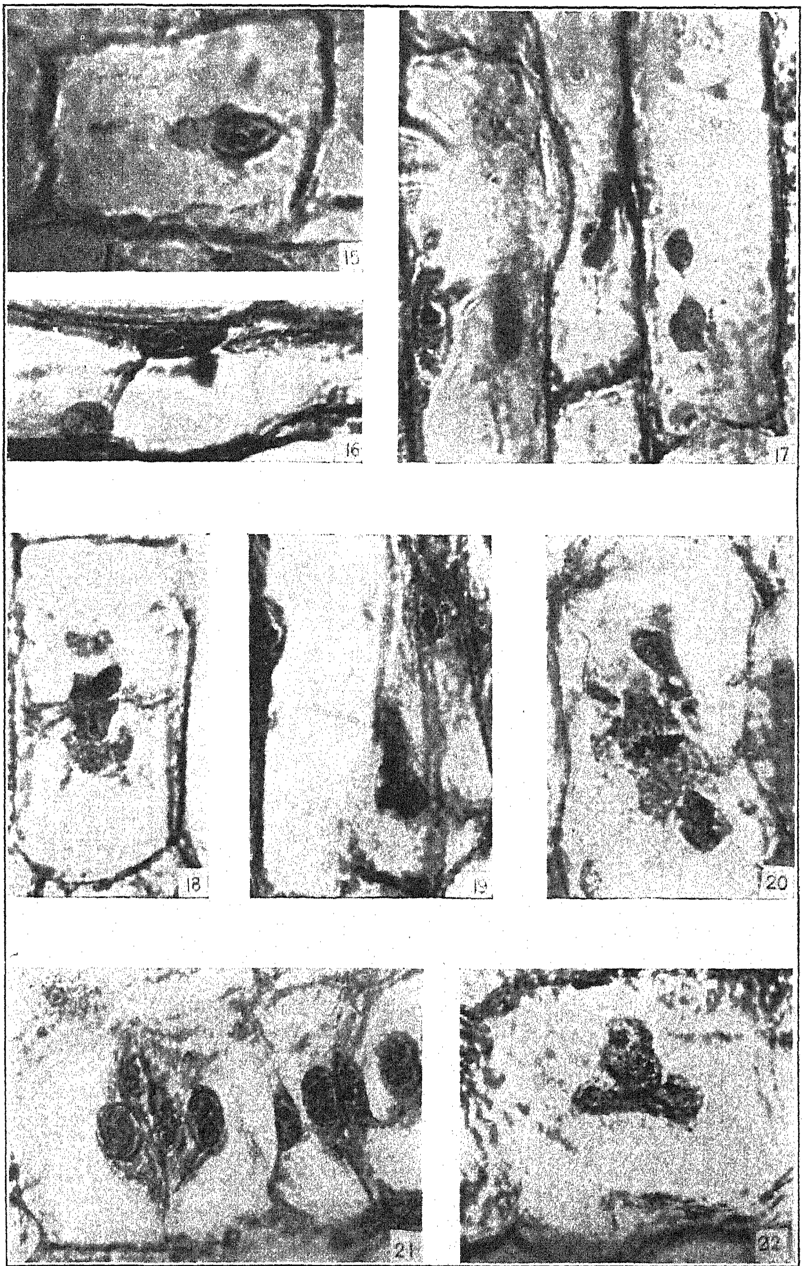
FIG. 22. A cell containing an irregularly shaped nucleus, within which lies a single nucleole, and an elongated x-body.



THE X-BODIES ASSOCIATED WITH DAHLIA MOSAIC



THE X-BODIES ASSOCIATED WITH DAHLIA MOSAIC



THE X-BODIES ASSOCIATED WITH DAHLIA MOSAIC

Experimental studies on head smut of corn and sorghum[1]

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(WITH PLATES 21–25)

The head smut of corn and sorghum caused by *Sorosporium reilianum* (Kühn) McAlpine is unusually interesting on account of its occurrence on both these hosts, which belong to two distinct genera of grasses—Zea and Holcus. Corn or maize is a new-world plant, having been brought into cultivation by the American Indians, and, since the discovery of the Western Hemisphere, the plant has been carried to various parts of the world; wherever adapted to the climatic conditions, as in Southeastern Europe, some parts of India, Australia and South Africa, it has become an important crop. Sorghums, on the other hand, have been cultivated for many centuries in various parts of the old-world, particularly China, India and parts of Africa. The wild forms, such as Sudan Grass and Tunis Grass, are distributed in Central and Southern Africa, Egypt, Madagascar and neighboring islands.

It is noteworthy that corn is attacked by another kind of smut, *Ustilago zeae* (Beckm.) Ung., which, so far as known, is incapable of attacking sorghum. This smut, usually known as common corn smut, is widely distributed and is recognized as one of the most serious diseases of this cereal. The sorghums also are attacked by several species of smut in various parts of the world, the most widely distributed being the covered kernel (*Sphacelotheca sorghi* (Link) Clinton), and loose kernel (*Sphacelotheca cruenta* (Kühn) Potter) smuts.

The head smut fungus was first described as *Ustilago reiliana* by Kühn (13) in 1875, his description being based on a specimen on sorghum from Egypt which Dr. Reil sent to him in 1868. Cooke (5), in 1876, collected head smut on corn in India, describing it under the name of *Ustilago pulveracea*, and Passerini (21) in the same year described a form on corn in Italy as *Ustilago reiliana* f. *zeae*. The fungus is now known to be widely distributed on both crops and has been recorded from practically all regions where sorghum and corn are extensively grown (24).

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Head smut was first recorded on sorghum in the United States in 1890 by Failyer and Willard (8), who collected a single specimen on Red Liberian Sorgo in Kansas. Professor S. M. Tracy (24) collected specimens on sorghum in November, 1888, at Starkville, Mississippi, but no record was made until later (25). Since its discovery the fungus has been recorded on sorghum from several states. As a rule it is not particularly common, occurring only sporadically, but in the Panhandle Region of Texas, it is recognized as a parasite of considerable economic importance.

Norton (19) made the first record of its occurrence on corn in the United States in 1895, and during that season it apparently was not uncommon in certain fields in Kansas. The disease, however, has not been frequent on corn in the United States, being practically unknown east of the Great Plains, including the great Corn Belt. It has, however, been found recently by Mackie (14) in a field of King Philip maize near Stockton, California and Dana and Zundel (6) in 1919 found it in two fields in the vicinity of Pullman, Washington, in one field 40 per cent of the plants being smutted. Parker (20) has more recently noted its wide distribution in that State. The fungus is common, and causes a serious disease in parts of Australia (16), South Africa (7, 17, 18) and India (2).

Head smut appears to be a characteristic systematic disease. The parasite enters primarily through the young seedling and continues its development as the host increases in size. There is no special indication of stunting of an infected sorghum plant; in fact there is practically no indication of infection until about the time that the plants are ready to head out. Just previous to heading, the infected plants can be distinguished from the normal by the more rapid enlargement of the panicle enclosed by the sheath of the upper leaf. Frequently the terminal head is entirely converted into a smut ball, which is more or less cylindrical in shape. It is rather hard and firm and covered with a thick white membrane which easily splits and exposes the spores surrounding the remnants of the vascular tissue of the various parts of the panicle. In some cases, branches of the panicle escape infection, the smutted portions being confined to single branches, or even spikelets. Usually small pustules of spores are found on these, but there are also cases in which the spikelets are stimulated to develop into a leafy shoot without further indication of the formation of spores. Sometimes the terminal head of the plant is entirely sound, but smutted lateral heads arise from the upper nodes of the main stem. In still other cases the main stem may produce only sound heads, while secondary stems arise from the ground level which have their panicles converted into the characteristic smut balls (pl. 24 and 25).

On corn the smut balls appear on both the tassel and the ear. Occasionally the terminal part of the stem is transformed into one large pustule and, due to the shortening of the internodes, appears surrounded by a rosette of leaves. In other cases, the tassel shows more or less its usual form; some of the spikelets produce normal flowers with stamens while others are transformed into smut balls. Occasionally the infection is confined to individual spikelets of the tassel and frequently a characteristic development of shoot-like structures is stimulated. On the ear, the individual kernels are transformed into masses of smut spores. In the early stage they rapidly enlarge, remaining more or less distinct. Soon, however, the covering membrane disappears and the individual smut pustules more or less coalesce into a dusty mass of spores. Sometimes an excessive number of ear-like structures develop at the various nodes on the stem of the plant, each developing into a smut ball. The tassel may entirely escape infection, while the disease appears on the ear, no cases, however, being observed in which the tassel showed infection while the ears remained normal (pl. 21, 22 and 23).

A number of workers have endeavored to produce artificial infection of sorghum and corn by the head smut fungus. The usual procedure has been to inoculate the seed with the spores. Brefeld (1) reported that Kühn succeeded in producing infection of sorghum with both head smut and loose kernel smut on the same plant. Passerini (22) was able to infect corn, but not sorghum, using spores collected on the former. Kellerman (10, 11) and Kellerman and Jennings (12) carried out a large number of inoculation experiments without, however, having obtained any marked degree of success in securing infection. McAlpine (15) succeeded in infecting only one corn plant by seed inoculation, while Clinton (4) and Hori (9) obtained entirely negative results in their experiments.

Potter (23) has made an extensive study of the life history of head smut. He also obtained essentially negative results when he tried to infect sorghum plants by inoculating the seed with spores and he then tried other methods of inoculation, such as mixing the spores with the soil and covering the seed or seedlings with this mixture. By these procedures he was able to obtain a considerable degree of success and as a result of his studies he came to the conclusion that the occurrence of infected plants is due to the presence of spores in the soil, where they may retain their viability for considerable periods of time. He also concluded that seed-borne spores are of minor importance in producing infection.

Christensen (3) has recently recorded the results of his studies on the relation of soil temperature and soil moisture to the occurrence of head smut of sorghum. His method of inoculation consisted of planting the seed in a soil mixed with the spores of the fungus. He was able to secure infected plants over a wide range of temperature—16 to 36° C.; a comparatively dry soil proved much more favorable for infection than a moist soil, his highest infection being 46.5 per cent.

Potter (23) concluded that the soil at the Amarillo Field Station, Texas, where many of his experiments were carried out, was thoroughly infested with the spores of head smut. A large number of varieties of sorghum have been grown at this Station by the Office of Cereal Investigations (24), and the occurrence of head smut on them has been recorded, the observations being made during the years 1916, 1917 and 1919. It is interesting to note that Feterita, the Milos and Broom Corn proved to be entirely free from infection. An occasional infected plant was found among the Kafirs and Kaoliangs, while the Sorgos as a group proved to be susceptible. The results, however, indicated that only eight varieties of sorghum grown during these years gave indications of moderate susceptibility. These were Black Amber, Minnesota Amber, Early Rose, Red Amber and Coleman Sorgo, Brown and White Durra and Giant Schrock Sorghum. Since the infections depended upon spores present in the soil, it was not possible to be certain of a thorough inoculation of every plant. Equal opportunities for the penetration may have been lacking, due to the unequal distribution of the spores in the soil. However, the observations showed that certain groups of sorghum consistently remained free from head smut.

The studies here reported are mainly concerned with the question regarding the possible relation between the head smuts on corn and on sorghum. They are recognized as belonging to the same species, as no morphological differences are observable which might serve to distinguish them. The records of their occurrence, however, indicate that the fungus may be present on one host in a given locality, while in a different area the other host is the one affected. This may be due in part, at least, to the fact that the crops are not generally grown in the same localities. However, a certain amount of overlapping occurs in the areas of their cultivation, and hence if the disease is common on one host, it might be expected to be more or less frequent on the other. In Western Kansas and Texas head smut on certain varieties of sorghum is fairly common. No recent records of its occurrence on corn have been made. In Washington the disease has been noted as rather severe on corn. It is also common on corn in Kashmir, India, and somewhat less frequent in the Punjab and Northern Bombay. In other parts of India the disease occurs on sorghum, being more frequent in Bombay. It is also fairly common on corn in parts of Australia, but has not been reported upon sorghum. The question arises, then, as to whether the two smuts are identical in their capacity for infection or whether they show distinct physiologic specialization.

In carrying out these investigations, it has been necessary to try various methods of inoculation. Some experiments have also been made regarding the influence of various environal factors on infection.

METHODS AND RESULTS FOR 1924

A series of experiments with the head smut of sorghum was carried out in 1924. The variety Red Amber Sorgo, which was known to be moderately susceptible to this disease, was inoculated with spores collected on this variety during the previous season. The usual procedure was to place the dry seeds or seedlings on soil in a paraffin cup; these were then covered with a mixture of spores and soil, prepared by adding a definite quantity of spores to the soil. The spore-soil mixture was applied at once or after standing a definite number of days. In most of the experiments the soil contained a moisture of about 40 per cent of its water holding capacity, and the seedlings were germinated in the laboratory, where the temperature usually varied from

18 to 22° C. After emerging from the soil they were transplanted to the field, where they were allowed to grow to maturity.

Three distinct series of experiments were carried out, the results being given in table 1. In the first series a freshly prepared mixture of spores in soil was placed over seedlings which varied from one to seven days old. At the end of one day the only signs of germination were the increased size of the seed. At the end of two days, however, the average length of the plumule was 2 millimeters. As the seedlings grew older the length of the plumule increased until at the end of the seventh day it varied from 4 to 6 centimeters in length. In this series infections occurred in the experiments where the seedlings used

TABLE I

Inoculation experiments with head smut of sorghum—1924. Spores from Sorgo on Red Amber Sorgo

SERIES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEEDLINGS	TOTAL NO. OF PLANTS	NUMBER INFECTED	PERCENTAGE INFECTED	LENGTH OF PLUMULE AT TIME OF INOCULATION
	days	*days*				*mm.*
I	0	1	16	5	31.2	
	0	2	10	2	20.0	2
	0	3	20	9	45.0	3- 5
	0	3	14	4	28.5	5-10
	0	4	15	4	26.7	10-20
	0	5	7	0	0	20-30
	0	7	10	0	0	40-60
II	1	1	20	12	60.0	
	2	2	18	3	16.7	2
	3	3	19	0	0	5-10
	4	4	22	5	22.7	10-20
	5	5	17	1	5.9	20-30
	7	7	14	0	0	40-60
III	1	0	10	2	20.0	
	2	0	18	5	27.8	
	3	0	17	2	11.8	
	4	0	18	0	0	
	5	0	15	0	0	
	6	0	15	0	0	
	8	0	17	0	0	
	9	0	15	0	0	
	10	0	15	0	0	

were one to four days old, the percentage of smutted plants varying from 20 to 45 per cent. No infection occurred in seedlings that were five and seven days old respectively. The results indicate that infection readily occurs by means of a fresh spore-soil mixture on seedlings whose plumule is not over 2 centimeters in length.

The second series of experiments consisted of inoculating seedlings successively one to seven days old with a spore-soil mixture of a corresponding age. Infections occurred in all except two of the experiments. A three day old spore-soil mixture gave negative results on seedlings three days old, but this was probably an accidental result in the experimentation. The seven day old spore-soil mixture also gave negative results on seedlings of the same age. In the other successful experiments the percentage of infection varied from 5.9 to 60 per cent. The latter occurred in the experiment in which seedlings one day old were inoculated with a spore-soil mixture which had been prepared for one day.

In the third series, dry seeds were inoculated with spore-soil mixtures of various ages, from one to ten days. Infection occurred in the first three experiments in which the spore-soil mixture was one to three days old, 11.8 to 27.8 per cent infection resulting. Negative results were obtained in the other experiments.

METHODS AND RESULTS FOR 1925

Two sets of experiments were carried out in 1925, in one of which the spores of head smut collected on Red Amber Sorgo in the experiments of the previous year were used for inoculation, and, in the other, spores collected on corn were used. The head smut on corn was obtained from Dr. F. D. Heald and Dr. E. F. Gaines of the Washington Agricultural Experiment Station, who kindly collected and forwarded it for our experimental purposes. The data are recorded in table 2.

Methods and results with head smut from corn. The experiments with the head smut from corn were started July 1 to 3. The germinations were carried out in the laboratory, where the temperature varied from 18° to 22° C. and the inoculated seedlings were planted in a sandy soil which contained about 40 per cent of its water holding capacity.

TABLE 2

Inoculation experiments with head smut of corn and sorghum—1925

SOURCE OF SPORES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEEDLINGS	ON CORN			ON SORGO		
			Total no. of plants	Number infected	Percentage infected	Total no. of plants	Number infected	Percentage infected
	days	*days*						
Spores from corn	0	0	37	7	18.9	38	0	0
	0	3	37	11	29.7	33	0	0
	1	1	61	48	78.6	93	0	0
	3	3	30	21	70.0	25	0	0
Spores from Red Amber Sorgo	0	0	49	0	0	43	10	23.2
	1	0	—	—	—	42	4	9.5
	1	1	213	0	0	212	10	4.7
	3	3	49	0	0	43	3	6.9

In one series of experiments a freshly prepared mixture of spores and soil was applied to dry seed of both corn and sorghum, and also to seedlings 3 days old; 18.9 and 29.7 per cent of the corn plants respectively were infected. In a second series of experiments a spore-soil mixture one day old was applied to seedlings of the same age and 78.6 per cent of the corn plants were infected. Finally, a spore-soil mixture three days old was applied to seedlings of the same age, 70 per cent infection being obtained. The Red Amber Sorgo inoculated in the same series of experiments gave no infection, a total of 189 plants being grown in the three series.

Methods and results with head smut from sorghum. Most of the experiments with the head smut of sorghum were started on May 23 to 25. A number of different experiments were carried out, involving variations in the nature of the soil, its moisture content, the temperature and age of seedlings. In many of these entirely negative results were obtained, and most of them seemed to be without special significance. In table 2 are recorded the data for the experiments, which correspond rather closely to those carried out with the head smut of corn.

The highest percentage of infection of Red Amber Sorgo was obtained when a fresh spore-soil mixture was applied to the dry seed, 23.2 per cent of the plants being smutted. In all the other experiments a comparatively low percentage of smutted plants resulted. In these experiments corn also was inoculated with the spores from sorghum, but no infections occurred, although a total of 311 plants were inoculated and grown to maturity.

METHODS AND RESULTS FOR 1926

A much more extensive series of experiments, in which spores of head smut collected during the previous season on both corn and sorghum were used for inoculation, was carried out in 1926. The methods consisted in various modifications of those used during the previous season. Generally, the seeds or seedlings were placed on moist soil in a paraffin cup and covered to a depth of about ¼ inch with a mixture of spores and soil, the amount depending upon the size of the seedlings. The cup was then filled with additional moist soil to the required depth and germination continued in the constant-temperature tank at 20° C. Soon after emerging, the seedlings were transferred to the field, where they grew to maturity.

The spore-soil mixture consisted of one part of spores to four parts of soil. The freshly prepared mixture was applied to the dry seed or seedlings in one series of experiments, and after standing at room temperature for a definite number of days, in the others. In most of the experiments thirty seeds or seedlings were inoculated, and in the case of sorghum, these were all placed in one paraffin cup, but on account of the size of the corn seedlings, only ten or fifteen were planted in a cup. Previous to inoculation the seeds were germinated between moist filter paper in Petri dishes and, so far as possible, seedlings of the same size were selected for the inoculation. No accurate measurements of the size of the plumule were kept, but they corresponded, in a general way, to those recorded in table 1.

Results with spores of head smut from corn. Five series of experiments were carried out in which various combinations of spore-soil mixtures and seed or seedlings were used, the data being summarized in table 3. In the first series a freshly prepared spore-soil mixture was applied to dry seeds or seedlings, one to three days old; in every case high percentages of infection, varying from 76 to 91.6 per cent, were obtained. In the second series of experiments the spore-soil mixture was one day old, and this was applied either to dry seeds or seedlings one to three days old; in this case also high percentages of infection, ranging from 75.8 to 90 per cent were secured. A two day old spore-soil mixture was used in the third series, and again high percentages of infection resulted, varying from 38.4 to 78.2 per cent. In the fourth series the spore-soil mixture was three days old, and the percentages of infection also were very high, varying from 76.6 to 88.8 per cent. In the fifth series a four day old spore-soil culture was used for inoculation. No infection occurred on the dry seeds or seedlings one day old. Negative results were also obtained on the seedlings four days old, while the three day old seedlings gave 51.7 per cent, and those two days old gave 80.7 per cent infection.

TABLE 3

Inoculation experiments with head smut of corn—1926

SERIES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEEDLINGS	ON CORN			ON SORGO		
			Total no. of plants	Number infected	Per-centage infected	Total no. of plants	Number infected	Per-centage infected
	days	*days*						
I	0	0	24	22	91.6	28	0	0.0
		1	25	19	76.0	18	0	0.0
		2	29	24	82.7	20	1	5.0
		3	30	24	80.0	16	0	0.0
II	1	0	29	22	75.8	20	0	0.0
		1	29	26	89.6	25	0	0.0
		2	30	27	90.0	23	0	0.0
		3	28	24	85.7	25	5	20.0
III	2	0	26	10	38.4	25	0	0.0
		1	23	18	78.2	18	0	0.0
		2	22	16	72.7	27	0	0.0
		3	21	15	71.4	13	0	0.0
IV	3	0	30	23	76.6	29	0	0.0
		1	24	20	83.3	22	0	0.0
		2	28	24	85.7	29	3	10.3
		3	25	22	88.8	24	1	4.1
V	4	0	30	0	0.0	28	2	7.1
		1	29	0	0.0	27	4	14.8
		2	26	21	80.7	30	4	13.3
		3	29	15	51.7	28	2	7.1
		4	29	0	0.0	28	0	0.0

These results indicate very clearly that the corn is highly susceptible to head smut from the same host, since high percentages of infection over a comparatively wide range of conditions were obtained. There appeared to be no significant differences in the results when a fresh spore-soil mixture was used for inoculation or one that had been prepared for two to three days. Further, it seemed to make no essential difference whether dry seeds or seedlings two to three days old were inoculated. When, however, the spore cultures were four days old, differences were apparent, depending upon the age of the seedlings.

In the same series of experiments, in which Red Amber Sorgo was inoculated with spores from corn, negative results for the most part were obtained. A few smutted plants were observed, the greatest number being found in the fifth series, in which a four day old spore-soil culture was used for inoculation. In all of the experiments only 22 plants out of a total of 503 were infected. In many of these plants the main terminal head was normal, but secondary lateral smutted panicles developed. The Red Amber Sorgo, while not entirely free from attack, yet showed distinctly a high degree of resistance to the smut from corn.

Results with head smut of sorghum. The methods employed were essentially the same as with the head smut of corn, and a similar series of experiments was carried out (table 4). In the first series a fresh spore-soil mixture was placed upon dry seeds and seedlings one to three days old. The percentage of infection varied from 33.3 to 66.6 per cent. The second series of experiments, in which the spore-soil mixture was one day old, gave a somewhat higher percentage of infected plants, the variation ranging from 73.3 to 84.6 per cent. In the third series, a two day old spore-soil mixture was used, but the percentage of infection was well below that obtained in the previous series, the lowest being 25 per cent, when the dry seed was inoculated, and the highest 51.7 per cent, when three day old seedlings were inoculated. In the fourth series a three day old spore-soil mixture was used, and the highest percentage of infection in this series was 30 per cent, when the dry seed was inoculated. In the final series, a four day old spore-soil culture was used, and the highest percentage of infection obtained was 20 per cent. This occurred in the two experiments where two day old and four day old seedlings were inoculated.

TABLE 4

Inoculation experiments with head smut of sorghum—1926

SERIES	AGE OF SPORE-SOIL MIXTURE	AGE OF SEED-LINGS	ON CORN			ON SORGO		
			Total no. of plants	Number infected	Per-centage infected	Total no. of plants	Number infected	Per-centage infected
	days	*days*						
I	0	0	29	0	0.0	30	20	66.6
		1	26	1	3.8	10	5	50.0
		2	30	0	0.0	20	11	55.0
		3	25	0	0.0	24	8	33.3
II	1	0	29	0	0.0	28	20	71.4
		1	26	0	0.0	15	11	73.3
		2	29	1	3.4	24	19	79.1
		3	28	0	0.0	26	22	84.6
III	2	0	26	0	0.0	32	8	25.0
		1	29	0	0.0	29	8	27.5
		2	29	2	6.8	28	9	32.1
		3	28	3	10.7	29	15	51.7
IV	3	0	26	0	0.0	30	9	30.0
		1	30	0	0.0	25	6	24.0
		2	28	1	3.5	36	4	11.1
		3	29	0	0.0	33	5	15.1
V	4	0	30	1	3.3	39	5	12.8
		1	29	2	6.8	27	1	3.7
		2	30	0	0.0	25	5	20.0
		3	30	3	10.0	32	6	18.7
		4	30	1	3.3	25	5	20.0

In the similar series of experiments in which corn was inoculated with the spores from sorgo, an occasional plant was found to be infected; out of a total of 596 in the entire series 15 plants were smutted. The evidence is quite clear that sorghum smut does not readily pass over on to corn, although to some extent it appears to be able to infect the latter host.

Influence of temperature and moisture on infection. A few experiments were carried out in which corn was inoculated with spores from the same host and germination continued in sand with varying amounts of moisture. There were four experiments in which the percentage of the water-holding capacity of the soil was approximately 20, 40, 60 and 80 per cent. In each case a one day old spore-soil mixture was applied to seedlings of the same age. Comparatively high infections were obtained in each experiment, the lowest being 42.3 per cent in the 40 per cent moisture and the highest 71.4 per cent in the 60 per cent moisture; 50 per cent of the plants in the low moisture were infected and 51.8 per cent of the plants in the high moisture.

A similar series of experiments was carried out with Red Amber Sorgo inoculated with spores from this host, and the following percentages of infection were obtained: 19.3 per cent in the 20 per cent moisture; 3.5 per cent in the 40 per cent and also the 60 per cent, and no infected plants in the 80 per cent moisture.

Three experiments were carried out in which variations in temperature were employed. Seedlings one day old were inoculated with a spore-soil mixture of the same age, and germination continued in soil at 20°, 25° and 30° C. The corn plants inoculated with spores from corn gave 89.6, 77.2 and 84.6 per cent infection respectively; thus all these temperatures appeared to be equally favorable for the infection of the corn. With the Red Amber Sorgo inoculated with spores from sorgo, the percentages of infection at these three temperatures were 73.3, 29 and 18.9 per cent, respectively. The data suggest that a temperature of 20° is more favorable than either 25° or 30° for the infection of the sorgo.

Varietal susceptibility. A very few varieties of corn were inoculated with spores from corn. In each case one day old seedlings were inoculated with a spore-soil mixture of the same age and germination continued in soil. The results obtained were as follows: Australian Pop 48 per cent; Golden Bantam Sweet 35 per cent; King Philip Flint 66.6 per cent; Leaming Dent 66.6 per cent; Pawnee Flour 60 per cent and Washington Dent 82.1 per cent. In a similar series in which sorghum varieties were inoculated with spores from Red Amber Sorgo, using the same methods, the following results were secured: Black Amber Sorgo 38.4 per cent; Coleman Sorgo 75 per cent; Early Rose 22.7 per cent; Red Amber Sorgo 61.1 per cent; Brown Durra 3.5 per cent; Schrock Sorghum gave negative results.

DISCUSSION

The results for 1925 indicated that the corn smut would not go over on to the sorghum, since no infection occurred in a total of 189 inoculated plants, although 87 corn plants out of a total of 165 were infected. These results showed quite clearly the high degree of susceptibility of the corn to the smut. It was further found that the sorghum smut would not pass over on to corn, a total of 311 plants being inoculated. Unfortunately, the percentage of infection of sorghum with spores from the same host was very low, only 27 plants out of a total of 340 being infected.

In 1926, however, a few corn plants inoculated with spores from sorghum and a few sorghum plants inoculated with spores from corn were smutted. Since the experiments with each smut were started at different times, and special care taken to avoid contamination, the evidence indicates that the smut may to some extent pass from one of the hosts to the other. The corn, however, appeared to be much more readily infected than the sorghum with its own smut, since quite high infections were secured over a comparatively wide range of conditions. While comparatively high percentages of infection were obtained with sorghum, using the sorghum smut, yet in general they did not approach those of corn.

The results indicate that the two smuts are distinct in their physiologic capacity for infecting these hosts, although they are not sharply limited to either corn or sorghum. The fact, however, that each smut proved capable of severely infecting its corresponding host while giving very low results from the other, indicates clearly the existence of specialization.

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Literature cited

1. **Brefeld, O.** 1883. Die Brandpilze I. In Unters. a. d. Gesammt. d. Myk. **5**: 91–95.
2. **Butler, E. J.** 1918. Fungi and disease in plants. Thacker, Spink & Co. 547 p.
3. **Christensen, J. J.** 1926. The relation of soil temperature and soil moisture to the development of head smut of sorghum. Phytopathology **16**: 353–357.
4. **Clinton, G. P.** 1900. The Smuts of Illinois agricultural plants. Illinois Agr. Exp. Sta. Bull. 57: 289–360.
5. **Cooke, M. C.** 1876. Some Indian fungi. Grevillea **4**: 114–118.
6. **Dana, B. F., and George L. Zundel.** 1920. Head smut of corn and sorghum. Washington Agr. Exp. Sta. Popular Bull. 119. 8 p.

7. **Evans, I. B. Pole.** 1911. Maize smut or "brand," *Sorosporium reilianum* (Kühn) McAlp. Agr. Jour. Union South Africa **1:** 697.
8. **Failyer, G. H., and J. T. Willard.** 1890. Experiments with sorghum. Kansas Agr. Exp. Sta. Bull. 16: 135–149.
9. **Hori, S.** 1907. Seed infection by smut fungi of cereals. Bull. Imp. Central Agr. Exp. Sta. Japan **1:** 163–176.
10. **Kellerman, W. A.** 1900. A foliicolous form of sorghum smut and notes on infection experiments. Ohio Nat. **1:** 9–10.
11. ————. 1900. Experiments with the sorghum smuts. Ohio State Acad. Sci. Ann. Rep. **8:** 18–19.
12. ———— **and O. E. Jennings.** 1902. Smut infection experiments. Ohio Nat. **2:** 258–261.
13. **Kühn, J.** 1875. *Ustilago reiliana.* Rabenhorst, Fungi Europaei Exsiccati, ed nova s. 2, cent. 20, No. 1998.
14. **Mackie, W. W.** 1920. Head smut in sorghum and maize. Phytopathology **10:** 307–308.
15. **McAlpine, D.** 1910. The smut of maize and its treatment. Jour. Dept. Agr. Victoria 8: 290–298.
16. ————. 1910. The smuts of Australia. Dept. Agr., Victoria. 288 p.
17. **Mundy, G. H.** 1910. Maize smut (*Ustilago maydis*). Rhodesia Agr. Jour. **7:** 1530–1532.
18. ————. 1910. Head smut of maize (*Sorosporium reilianum* Kühn (McAlp.)). Rhodesia Agr. Jour. **8:** 277.
19. **Norton, J. B. S.** 1895. *Ustilago reiliana* on corn. Bot. Gaz. **20:** 463.
20. **Parker, C. S.** 1921. Head smut of corn in Washington. Phytopathology **11:** 515.
21. **Passerini, Giovanni.** 1876. *Ustilago reiliana* J. Kühn forma: *zeae.* Rabenhorst, Fungi Europaei Exsiccati, ed nova s. 2, cent. 21, No. 2096.
22. ————. 1877. Funghi Parmensi. Fam. IV. Ustilaginei. Nuova Gior. Bot. Ital. **9:** 235–239.
23. **Potter, A. A.** 1914. Head smut of sorghum and maize. Jour. Agr. Res. **2:** 339–372.
24. **Reed, George M., and L. E. Melchers.** 1925. Sorghum smuts and varietal resistance in sorghums. U. S. Dept. Agr. Bull. 1284: 1–56.
25. **Tracy, S. M., and F. S. Earle.** 1895. Mississippi fungi. Mississippi Agr. Exp. Sta. Bull. 34: 79–122.

Explanation of plates

PLATE 21

Head smut on corn. One figure shows a stalk with four smut balls in the axils of the leaves. The other figure shows a smutted ear.

PLATE 22

Head smut on corn. The two figures at the left show ears infected with the smut, the spores still nearly enclosed by the white membrane. The middle figure shows smut balls on the tassel. The figure at the right shows the entire upper portion of the stem converted into a smut ball.

PLATE 23

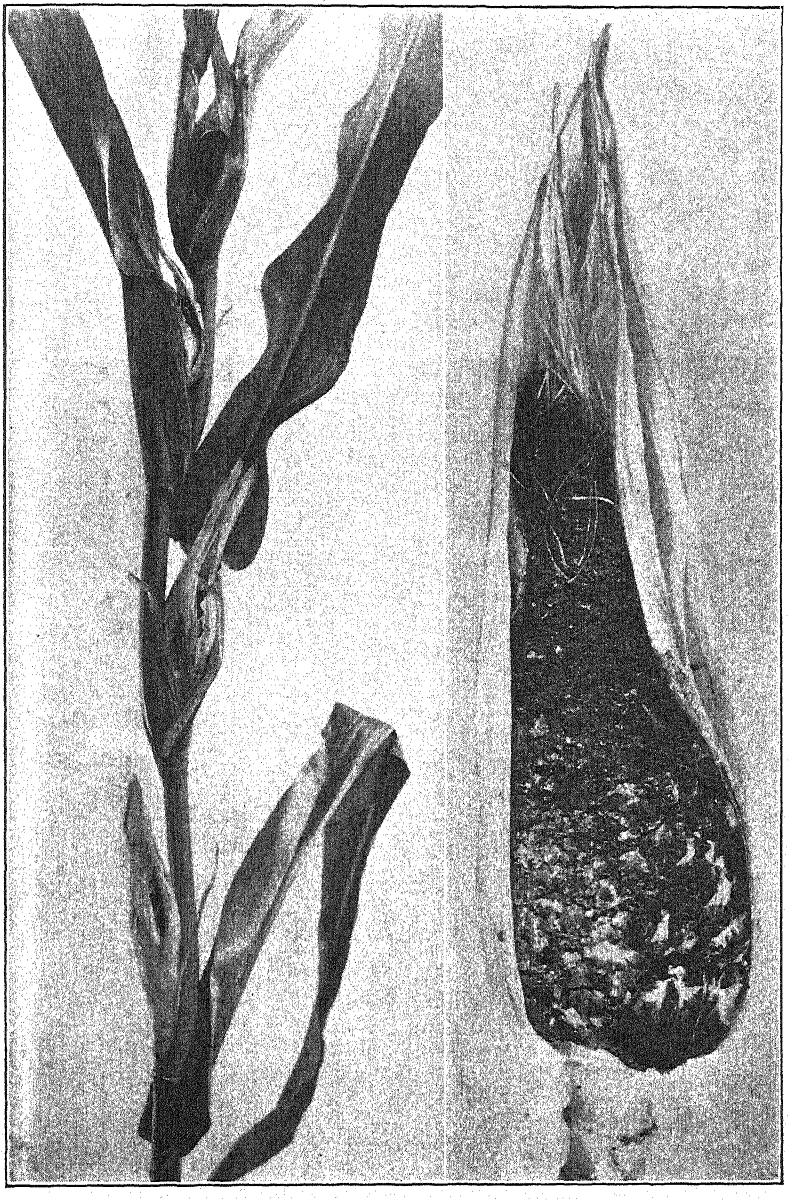
Head smut on corn. The figures show various types of tassel infection.

PLATE 24

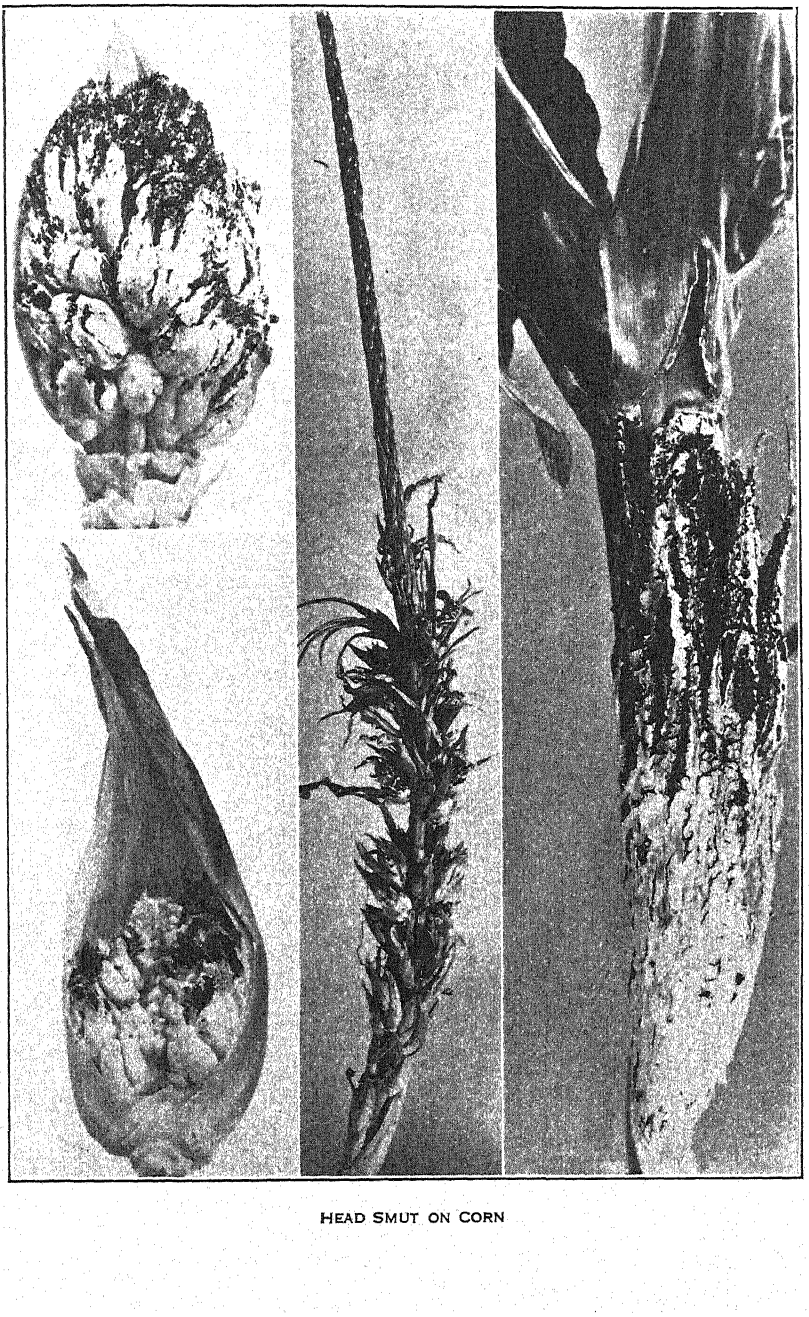
Head smut on Red Amber Sorgo. Various types of panicle infection, involving single spikelets, small and larger branches.

PLATE 25

Head smut on Red Amber Sorgo. Practically the entire panicles are involved.



HEAD SMUT ON CORN



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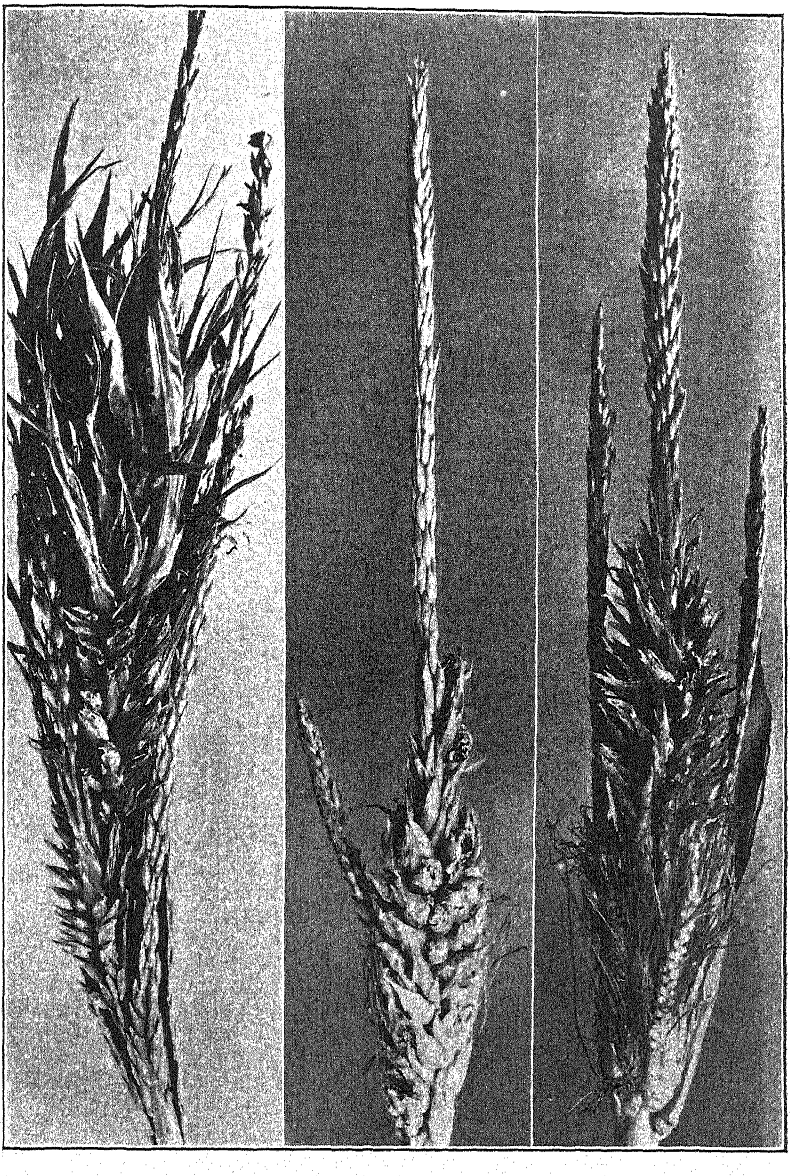

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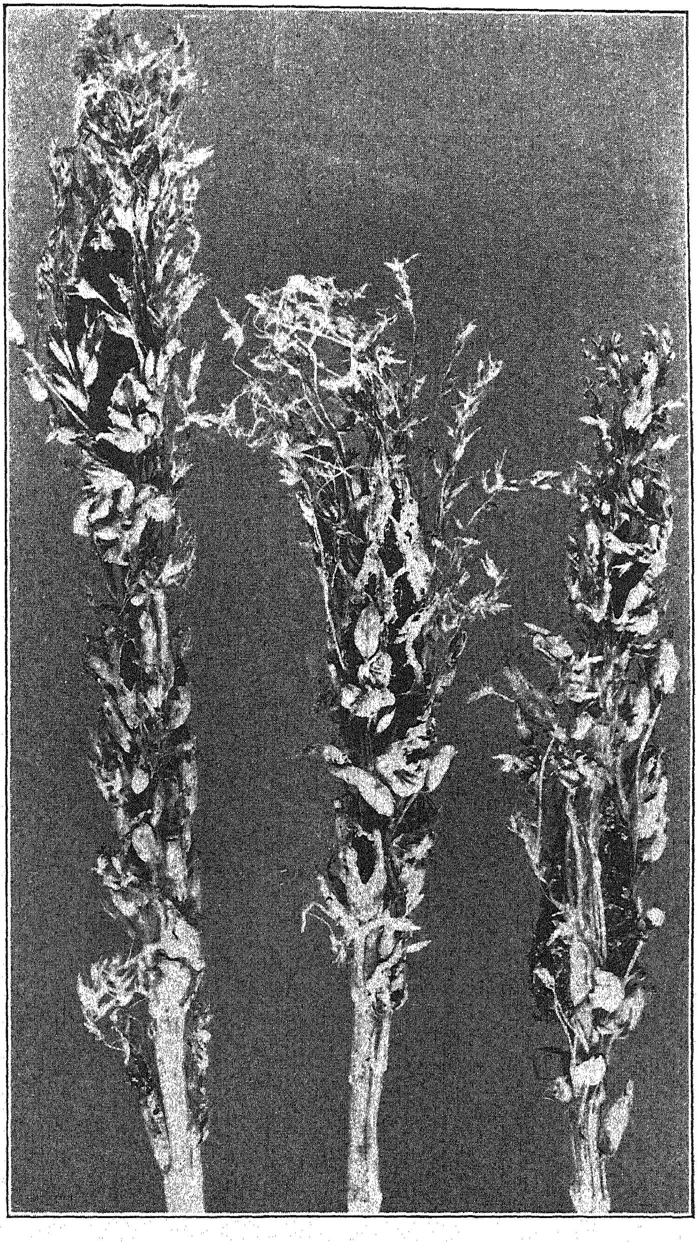
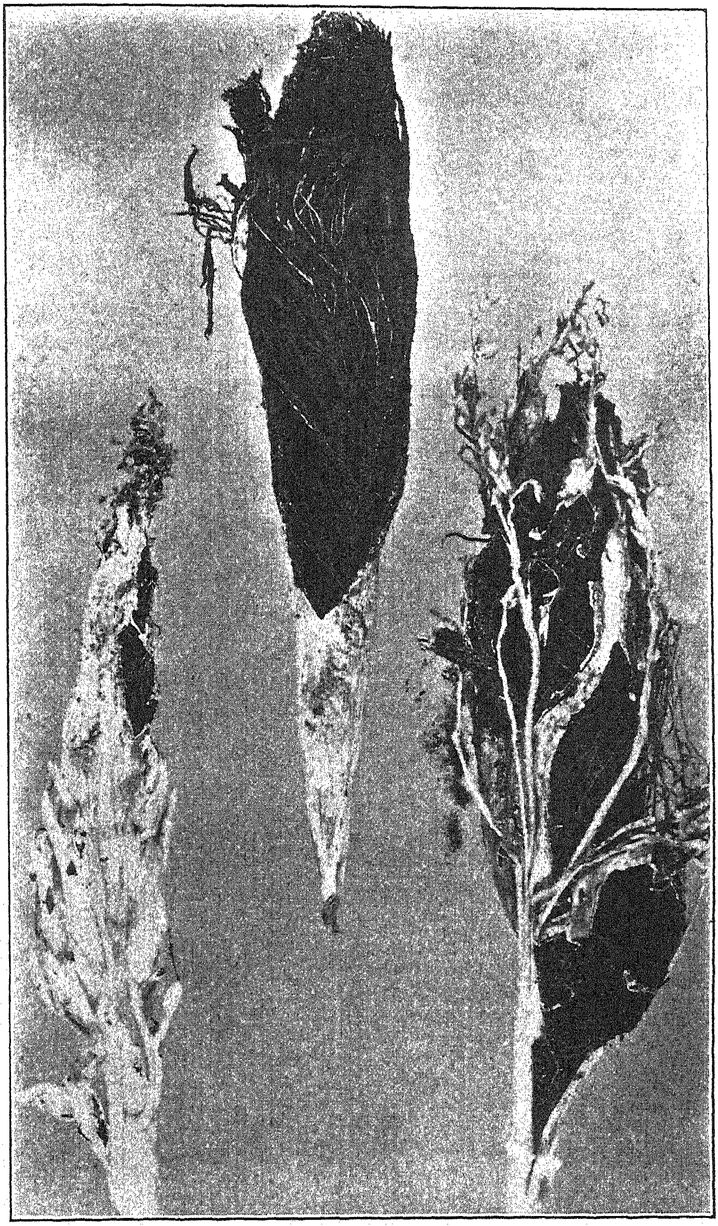


HEAD SMUT ON SORGO



HEAD SMUT ON SORGO

Additions to the genus Munnozia R. & P.

H. H. RUSBY

The genus *Munnozia* was founded by Ruiz and Pavon (Flor. Peruv. Chil. Prod. 108. *pl. 23.* 1794.), who published (Syst. Veg. Fl. Peruv. Chil. 195. 1798.) the four species *corymbosa*, *venossissima*, *lanceolata*, and *trinervis*. Weddell (Chlor. And. **1**: 211. 1855.) added *M. sagittata*, and Bentham (Pl. Hartw. 134. 1839.) *M. senecionidis*. De Candolle recognized the genus as valid in the Prodromus, but modern authors have treated it as a section of the now large and heterogeneous group *Liabum*. Bentham (Gen. Plant. **2**: 436. 1873.) recognizes nine sections of this genus, most of which will probably come to be recognized as valid genera. The group here treated appears to me to be fully entitled to this consideration.

The figures in Ruiz and Pavon are quite formal, and magnify certain characters, while minimizing others, so that the precise limitations there assigned require some modification, to include the entire natural group. The tridentate inner scales of the involucre are never quite as figured, and this character may be reduced to a mere serration, which, in other species, may disappear altogether. The rays are not always strictly limited to a single series, although I have not found them forming two complete series, in any case. The most important characteristic of the genus is not fully displayed in the figure referred to, and is not fully expressed in the statement "receptacle ciliate." The "cilia" in the species figured (*M. corymbosa*) are in reality narrow paleae or their laciniae, and these lacerate paleae I have found to be an invariable character in the genus, which, as represented by the species here enumerated, possesses the following characters.

Involucre hemispherical or short-campanulate, imbricate, the scales nerved, acute or obtuse, the outer usually successively shorter and broader and less or not at all acute, usually coriaceous, the innermost thin, chartaceous, usually glabrous, often hyaline, entire or more or less serrate or dentate above. Receptacle convex, foveolate, paleaceous, the paleae more or less dentate, laciniate or laciniate-ciliate, and more or less connate. Rays in one, or partly in two series, pistillate, fertile, elongated, nerved, usually minutely 3-dentate, at least the tube more or less pilose, purplish or yellow (or white?), the style elongated, with long, slender branches. Disk-flowers perfect and fertile, the slender cylindrical tube usually more or less pilose, the throat campanulate or infundibular, the lobes usually long, the style-branches various, usually rather short and stout.

The plants are usually erect shrubs, occasionally climbing or reclining, rarely erect herbs, and are mostly of high altitudes, 8000 feet or higher, in the South American Andes.

In foliage-characters, the genus presents two distinct types. In one, the leaves are coriaceous, green above and densely arachnoid beneath, the margins more or less denticulate, occasionally almost entire, and the form elongated. In the other, they are membranaceous, usually sagittate or hastate, and less, or even not at all arachnoid underneath.

Besides the species named above, the following transfers are proposed.

M. glandulosa *n. comb.*

Liabum glandulosum O. Kuntze. Rev. Gen. 3^2: 163. 1898.

M. hirta *n. comb.*

Liabum hirtum O. Kuntze, l. c.

M. giganteum *n. comb.*

Liabum giganteum Rusby, Bull. N. Y. Bot. Gard. **4**: 391. 1897.

M. Rusbyi Britton *n. comb.*

Liabum Rusbyi Britton, Bull. Torrey Club **19**: 263. 1892.

The following species, so far as I can determine, have not been described.

Munnozia foliosa n. sp. Branches and inflorescence scabrellate, the lower leaf-surfaces white, short-tomentose, the upper dark-green and apparently somewhat purplish, very minutely and sparsely puberulent, with white glistening hairs. Stems tall, stout, striate, purplish-brown, very leafy. Petioles to 2.5 cm. long, stout, scabrous, margined, grooved above, the bases slightly dilated and sub-connate. Blades to 15 cm. long, 5 cm. wide, lanceolate, with blunt or rounded base and acuminate and very acute summit, dentate with very small acute salient teeth and shallow rounded sinuses; thick, the indumentum as stated, the midrib prominent beneath, 2-channeled, the secondaries 10 or 12, with a few lesser intermediate ones, widely spreading, thin, strongly falcate-ascending, the venation coarsely anastomosing. Corymb terminal, small and few-flowered, compound, with few lance-linear or subulate bracts, the peduncles unequal, mostly short and stout. Involucre hemispherical, about 8 mm. high and nearly 2 cm. broad, the scales in about 4 series, the outer successively shorter, thick and coriaceous, scabrellate, obscurely nerved, broadly ovate, with blunt summit. Innermost scales short-acuminate and acute, obscurely serrate at the top. Receptacle chaffy, its scales narrowly lanceolate, somewhat lacerate at the summit. Rays about 3 cm. long, pilose throughout. Disk corollas pilose or hispid throughout, the tube 6 mm. long, uniformly and narrowly cylindrical, the throat 1.5 to 2 mm. long, the lobes 2 mm. long. Stamens and style long-exserted. Pappus 9 mm. long.

Collected by *M. Bang* near Cochabamba, Bolivia, 1891 (*No. 1195*). Distributed as *Liabum Rusbyi* Britton, but very distinct from that species. Also collected by *Otto Buchtien* at Unduavi, Bolivia, 10,000 ft., Nov. 1900 (*No. 3032*). Buchtien says "A shrub, to 2 meters high, with violet flowers."

Munnozia longifolia n. sp. More or less white-floccose throughout, excepting the upper leaf-surfaces. Stems woody, rather stout, quadrangular, the sides 2-sulcate, reddish-brown underneath the indumentum. Petioles to 2 cm. long, channeled. Blades to 15 by 3 cm., lanceolate, acute at the base and regularly long-acuminate and very acute at the summit, sub-entire or with a few distant minute teeth, thick and coriaceous, dark-green above, with the venation finely channeled, densely white-floccose beneath, the slender secondaries 12 to 14 on each side, strongly falcate and connecting a little way from the margin, the venation loosely and strongly anastomosing. Panicle terminal, very lax, the branches long and very slender, striate, sparsely subulate-bracted, the heads long and slenderly peduncled. Involucre hemispherical, 1.5 cm. broad, the scales in about 6 series, the outer successively shorter, broadly ovate or oval, coriaceous, tomentellate, brown, stoutly nerved, appressed, with recurved or spreading summit and margins, the summit rounded or obtuse. Innermost scales chartaceous, oblanceolate, obtuse, entire or minutely denticulate at the summit. Receptacle paleaceous, the chaff very short, subulate, serrulate, sub-hyaline. Ray-flowers 15 mm. long, pubescent, minutely 3-toothed, strongly 3-nerved, thickish, the style slightly exserted. Disk corolla pubescent, 8 mm. long, the regularly cylindrical tube half the length, the throat infundibular, 1.5 mm. long, the lobes 2.5 mm. long, thin, faintly nerved, the anthers almost equalling them. Pappus 7 mm. long, brown, coarse, unequal.

Collected by *Otto Buchtien* at Unduavi, Bolivia, 3300 meters, Nov. 1910 (*No. 3079*).

"A shrub."

Munnozia chrysanthemoidea n. sp. Minutely puberulent, the lower leaf-surfaces white-floccose. Stems shrubby, rather stout but weak, brownish-purple, strongly striate or grooved, in the dried state. Petioles to 2 cm. long, stout, margined, the margins minutely and sparsely serrate, the bases abruptly dilated and connate, thick and fleshy. Blades to 12 cm. or more long, and 5 cm. wide, very abruptly contracted into the petiole and with very abruptly short pointed acute or obtusish summit, finely dentate, the teeth triangulate, short, with cartilaginous dark points, the sinuses shallow and rounded; thick and somewhat rigid, the upper surfaces dark-green, the lower closely and densely white-floccose, the venation conspicuous, purplish-brown, the midrib broad, irregularly 3-ribbed, the secondaries 10 or 12 on a side, widely divergent at the base, then strongly falcate-ascending, the venation coarsely and strongly anastomosing. Panicle terminal, many-flowered, large and showy, bracted with miniature foliage-leaves, the peduncles elongated, slender, striate. Involucre hemispherical-campanulate, 1 cm. long, about 1.5 cm. broad, slightly concave at the base. Scales 3-nerved, all appressed, in about 5 series, coriaceous, the outer successively shorter, ovate, the outermost broader than long, with rounded green summit. Inner scales lanceolate, acuminate and acute, serrate toward the summit. Receptacle convex, densely chaffy, the scales narrow, acuminate, lacerate at the summit. Rays 3 cm. long, 3 mm. broad, oblanceolate, obtuse, minutely 3-toothed, 3- or 5- nerved below the middle, coarsely pilose at the base, the tube filiform, 8 mm. long. Exserted portion of style 5 mm. long, cleft nearly half-way. Tube of disk flowers narrowly and uniformly cylindric, 6 mm. long, the throat campanulate, 2 mm. long, pilose, the lobes 3 mm. long, ovate, acutish, 1-nerved. Anthers 3 mm. long, short-sagittate, exserted. Style thick, scabrous, much exceeding the stamens, the branches short and slender. Pappus pale, 1 cm. long, the outer little shorter than the inner.

Collected by *M. Bang* near Mapiri, Bolivia, 10,000 ft. (?), September, 1892, and distributed and published as *Liabum Rusbyi* Britton, from which it differs markedly in the form and proportions of the disk corollas, and in other ways. The plant is apparently a shrub, with handsome purple or rose-colored flowers.

Munnozia Ariste-Josephi n. sp. More or less white-floccose throughout, excepting the upper leaf-surfaces. Stems stout, apparently herbaceous. Petioles to 3 or 4 cm. long, slender. Blades (only upper seen) to 10 × 5 cm., ovate, mostly somewhat inequilateral, not hastate, short-acuminate and acute, irregularly sinnuate-dentate, the teeth broadly triangular, mostly obtuse; membranaceous, thin, dark-green and sparsely and very shortly strigose above, densely white or grey floccose beneath, sub-trinerved, the crooked secondaries about 8 on each side, Panicle ample, very lax, the branches opposite, with long linear attenuate bracts, the branchlets one-flowered, very slender. Involucre hemispherical, nearly 2 cm. broad, 1 cm. high, the scales in about 6 series, more or less floccose, finely nerved, all about equal, the outer herbaceous, all lanceolate, acuminate and very acute. Receptacle chaffy, the chaff regularly connate into infundibular calyces, with fimbriate and ciliate margins. Ray-flowers purple (?), 2 cm. long, the tube 3 mm., strongly pilose, the style long-exserted, very slender, like its branches. Disk-flowers 8 mm. long, the tube a little more than half, the lobes oblong, short, the style little exserted, the branches stout. Pappus of the disk-flowers 6 mm. long, the outer about two-thirds as long as the inner.

Collected by *Brother Ariste-Joseph*, at Guassia, Colombia, Sept. 1919 (*No. A 455*). The peculiarly connate chaff of the receptacle in this species apparently gives the "foveolate-ciliate" appearance described by Ruiz and Pavon in the type species of the genus.

Munnozia muricata n. sp. Stems coarsely short-pilose, the brachlets hispid with short, stout, divaricate hairs, the upper leaf-surfaces short-strigose, the inferior densely white-floccose. Stems shrubby, stout, but weak, perhaps climbing or reclining, reddish, irregularly angled and sulcate, the branchlets short, erect. Petioles to 3 cm. slender, sub-hispid, dilated at the base and sub-connate. Blades to 7 × 4.5 or 5 cm., triangular-ovate or sub-deltoid, acute, the base truncate, mostly more or less hastate, the basal lobes very small, the margin sinuate-dentate with short and broad triangular teeth, their tips indurated; membranaceous, above deep-green, below white, 3-nerved, the midrib more or less muricate, the venation coarsely and strongly anastomosing, reddish. Panicle small, contracted, the peduncles slender, reddish. Involucre hemispherical, 1 cm. broad, the scales in about 5 series, all ovate, acuminate and acute, the outer successively shorter and more abruptly acuminate, all equally thin and very strongly 5-nerved, brown, sparsely puberulent. Receptacle densely chaffy, the chaff rather long, lanceolate, acuminate and acute, densely lacerate-ciliate. Rays 2 cm. long, strongly 5-nerved, lightly 5-toothed. Disk-flowers 1 cm. long, the tube less than half the length, pubescent, the lobes 2.5 mm. long, the midrib very strong.

Collected by *Otto Buchtien* at Unduavi, Bolivia, 3300 meters, November 1910, (*No. 681*).

Munnozia deltoidea n. sp. (*Liabum hastatum* (Wedd.) Britton, Bull. Torrey Club, **19**: 263.) Through an error in publication, this name was written "hastatum," instead of "sagittatum," based on Weddell's *Munnozia sagittata*, which the plant very closely resembles, and which it was believed to be. This determination was followed in my publication of *Mr. Bang's No. 670.* In the light of much fuller information regarding this and related species, it now appears that this is distinct from *M. sagittata*, the leaves of which Weddell distinctly says are "not three-nerved, as in *M. venossisima*." So far as the very meagre description of the latter species discloses, our plant is not of that species, and it appears not to have a name. The description follows:

More or less white-floccose, the young stems, petioles, etc., sparsely pilose with short, stout, spreading hairs. Stems shrubby, the branches elongated, crooked and probably climbing or reclining, the branchlets angled and sulcate. Petioles (only the upper seen in the type specimen,) 2 cm. long, very slender, channeled above, dilated and connate or sub-connate at the base, with irregular small foliaceous stipuloid appendages. Blades to 7 cm. long and nearly as broad (the lower ones probably much larger), triangular-hastate, acute, the basal lobes large, triangular, acute, the margin very irregularly sinuate-dentate with triangular acute salient teeth; membranaceous, thin, dark-green and sparsely, almost imperceptibly puberulent above, densely white-floccose beneath, with the slender, reddish venation wholly uncovered, the principal veins 2-sulcate; 3-nerved from the base, 2 or 3 branches spreading into the basal lobes, the secondaries from the midrib about 6 or 8 on each side, crooked, intercommunicating at some distance from the margin, the venation very loosely anastomosing. Inflorescence terminal, sparse, long and slenderly branched, the branches bearing one or two heads. Involucre hemispherical, 1.5 to 2 cm. broad, 8 mm. high, somewhat gray-puberulent, the scales in 4 or 5 series, thickish, 3 or 5-nerved, appressed, the outer successively shorter, obtuse or acutish, the inner becoming acuminate and acute. Rays purple, 2.5 cm. long, the ligule 1.5 cm., strongly 5-nerved, the tube short-pilose, the style shortly exserted, the lobes short and rather stout. Disk-flowers 8 mm. long, pilose, the tube a little more than half, the lobes 2 mm. long, exceeding the stamens, the style puberulent, shortly exserted, the branches short, rather stout. Receptacle densely chaffy, the chaff short and small, ciliate-lacerate.

Besides the collections noted above, of which *Rusby's 1744* is the type, this species was collected by *Buchtien* (*No. 475*) at Unduavi, Bolivia, at 3200 meters. This specimen has leaf-blades to 15 × 10 cm., with much larger teeth, but it agrees perfectly, on dissection.

The species is allied to *M. corymbosa*, *M. muricata* and *M. Ariste-Josephi.*

Munnozia strigulosa n. sp. Grayish-floccose throughout, excepting the upper leaf-surfaces. Stems woody, stout, terete. Petioles to 4 cm. long, stout, channeled above and striate, moderately dilated at the base and sub-connate. Blades to 13 by 4 cm. (exclusive of the basal lobes), lanceolate, long-acuminate and acute, hastate, the basal sinus very shallow and broad, the basal lobes rather small, triangular-lanceolate, acute, widely spreading, the margin very irregularly sinuate-dentate, the teeth small, short, broadly triangular, mostly acute; membranaceous, thin, deep-green and very finely to rather coarsely strigulose above, densely yellowish-gray-floccose beneath, sub-five-nerved, the lowest pair of nerves recurved into the basal lobes, the secondaries 10 or 12 on each side, slender, crooked, the venation partly concealed in the indumentum. Panicle terminal, ample, loosely many-flowered, the branches elongated and slender, the lower in the upper leaf axils, linear-bracted, the bracts few and small. Involucre hemispherical, nearly 2 cm. broad, 8 mm. high, the scales few, in about 4 series, closely imbricated, brown-tomentellate, very strongly nerved or sub-costate, broadly ovate, ciliate, acute or the outermost obtusish and somewhat smaller. Rays yellow, 2 cm. long, the tube 3 mm., puberulent, the very slender style long exserted, its branches long and slender, the ligule faintly 3-nerved. Disk-flowers 8 mm. long, the tube about half the length, pubescent, the throat sub-cylindrical, as long as the tube, the lobes linear, slightly exceeding the stamens, the style little exserted, the branches very short. Pappus nearly equalling the corolla. Receptacle densely chaffy, the chaff short, ciliate-lacerate.

Collected by *F. W. Pennell*, along roadside, on a forested slope of Tequendema, Cundinamarca, Colombia, 2300 to 2400 meters, Sept. 15, 1917 (*No. 1970*). *No. 4432*, from the State of Bolivar, Cordillera Occidental, 2800 to 3100 meters, "a shrub with yellow flowers," is probably a form of the same, although its involucral scales are scarcely acute and are somewhat arachnoid. It is less likely that *No. 7450* belongs to this species. This is "a climbing shrub, with yellow flowers, from Mt. Santa Ana, Cauca, 2800 to 3000 meters, June 29–30, 1922. The base of this leaf is strictly truncate, and scarcely hastate. The base of the throat of the disk-corolla, externally, is strongly and stoutly pilose and the style-branches are longer.

Munnozia attenuata n. sp. White-floccose throughout, excepting the upper leaf-surfaces. Stems woody, slender, purple, striate. Petioles to 1.5 cm. long, narrowly margined, the margins upcurved, dilated and connate at the base. Blades to 10 by 2 cm., triangular-lanceolate, the base abruptly contracted into the petiole, regularly acuminate from the base to the attenuate summit, the margin sinuate-dentate, the teeth very small, salient; membranaceous, thin, deep-green and glabrous above, densely white-floccose beneath, the slender purple venation not covered, sub-trinerved, the slender crooked secondaries about 10 on each side. Panicle terminal, the lower branches in the axils of the upper leaves, the branches linear-bracted, elongated, slender, erect, mostly 1-flowered. Involucre hemispherical-campanulate, minutely puberulent, the scales in about 6 series, closely imbricate, the outer successively shorter, thick, coriaceous, strongly many-nerved, oval-ovate, obtuse, becoming acutish within. Rays light-yellow, 2 cm. long, the tube 6 mm., pilose, the ligule strongly 5-nerved, the styles very small. Disk-corollas 8 mm. long, the tube nearly half the length, pilose, the throat infundibular, the lobes lanceolate-linear, longer than the throat, the style little exserted, its branches very small. Akene short and broad, hispid, the pappus copious, 6 mm. long. Receptacle sparsely chaffy, the chaff very small, sparingly lacerate, some merely finely dentate, the summits finely attenuate.

Collected by *Rusby and Pennell* in the edge of a bog, at Balsillas, Huila, Colombia, 2000 to 2200 meters, August 3–5, 1917 (*No. 769*).

"A shrub, with light yellow flowers." It appears to be identical with *Lehmann's No. B.T. 1206*, from Ecuador.

Munnozia filipes n. sp. More or less white-floccose throughout, except the upper leaf-surfaces. Stems shrubby, very slender, more or less striate, or irregularly sulcate, the branches much elongated and very slender, bearing solitary heads. Petioles slender, to 3 cm. long, very narrowly margined, the margins upturned, minutely dentate. Blades to 10 × 2.5 cm., lanceolate, long-acuminate and acute, the base more or less truncate and hastate, the basal lobes very small, divaricate, the margin irregularly sinuate-dentate, the teeth very short, broad; membranaceous, above dark-green, roughish, underneath densely white-floccose, the secondaries about 6 or 8 on each side, slender, weak and crooked, connecting at some distance from the margin. Involucre hemispherical, densely white-tomentellate, to 2 cm. broad, the scales in about 6 series, the outer a little smaller, mostly acute, the inner thin and scarious, minutely ciliate toward the summit. Receptacle densely chaffy, the chaff elongated, brown, acuminate and acute, deeply and coarsely lacerate. Rays yellow, 2.5 cm. long, the tube 5 mm. long, slender, puberulent, the ligules strongly 5-nerved, minutely five-toothed, the style long-exserted, its branches long and slender. Disk flowers 8 to

9 mm. long, the tube a little more than half of the length, puberulent, abruptly dilated into the campanulate throat, which is minutely puberulent, 2 mm. long, the lobes lanceolate. Stamens slightly exceeding the lobes, the style long-exserted, pubescent, its branches very short. Akene short and broad, nerved, white puberulent, the brown pappus crooked, 6 mm. long, the outer but little shorter.

Collected by *Rusby and Pennell* in the forest west of Balsillas, Colombia, 2,000 to 2200 meters, Aug. 3–6, 1917 (*No. 911*, the type.) Also *No. 634* from the same place, and *Pennell's No. 7113* from the Cordillera Central, altitude 3000 to 3200 meters, June 17, 1922. Of this, Pennell says "A climbing shrub, with yellow flowers." Its leaves are shorter, ovate, and somewhat cordate, and its inflorescence is much more compact. There are other slight differences in the flower characters, and it may well be found later to be a distinct species.

Munnozia laxiflora n. sp. White-floccose, excepting the upper leaf-surfaces. Stems herbaceous, very slender, widely branching. Petioles to 5 cm. long, channeled, dilated and connate at the base. Blades to 12 × 5 cm., ovate, acute, the base cordate with wide and very shallow sinus, usually very slightly hastate; membranaceous, above deep-green, minutely strigulose, beneath densely white-floccose, the margin finely sinuate-dentate, the secondaries 8 or 10 on each side, slender and weak, at an angle of about 45 degrees, inter-connecting at some distance from the margin. Panicle compound, very large and lax, the bracts lance-linear, the peduncles long and slender. Involucre hemispherical, 2 cm. broad, the scales in 5 or 6 series, tomentose, ovate with rounded summit, becoming acuminate and acutish within, entire, strongly many-nerved, the outer successively shorter. Receptacle strongly chaffy, the chaff elongated, acuminate, lacerate. Ray flowers yellow, 2.5 cm. long, narrow, oblanceolate, strongly 5-nerved, pubescent, the tube very short, hispid, the summit nearly entire. Disk-flowers 1 cm. long, puberulent, the tube half the length, abruptly expanded into the campanulate throat, which is a little shorter than the linear, thin, hyaline lobes. Stamens shorter than the corolla-lobes, the style equalling the lobes, its branches rather short, stout.

Collected by *Pennell and Killip*, in the Cordillera Central, Colombia, July 11–12, 1922, above tree level, 3300 to 3400 meters (*No. 6518*).

Apparently belonging to this species are *Triana's No. 1150* from New Granada and *Sodiro's No. 594*, from the mountains of Alacatzo, Ecuador. This has been called *Liabum sagittatum* by

Schultes-Bipontinus, but this name cannot obtain under *Munnozia*, as it is preoccuppied. *Pennell's 3154*, a tall herb from the Murillo Road, Tolima, is identical with Triana's plant.

COLLEGE OF PHARMACY,
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Notes on Fabaceae—IX

PER AXEL RYDBERG

HAMOSA (CONTINUED)

5. LEPTOCARPAE

This group was proposed by Jones as a section of *Astragalus*. It constituted a part of Gray's section MICRANTHI. Evidently Dr. Gray named his section from *Astragalus micranthus* Nuttall, which is the same as *A. Nuttallianus*. In dividing the section therefore, Jones applied the name MICRANTHI to the wrong part of the section when he used it for the perennial Mexican species. He should have applied it to this group. As the name *A. micranthus* Nuttall is a homonym, however, it is better not to use a sectional or group name based on the same, and I have abandoned the name MICRANTHI altogether.

The group is characterized by the annual habit, the few-flowered inflorescence, the small or rarely middle-sized flowers, the narrow pod—in the typical species strongly flattened—and the comparatively short calyx-tube often not longer than the teeth.

- Calyx black-hairy; pod little or not at all compressed; calyx-teeth shorter than the tube.
  - Pod glabrous, less than 2 cm. long.
    - Leaflets cuneate or oblong-cuneate, truncate or retuse at the apex, less than 8 mm. long. 22. *H. Bruceae*
    - Leaflets linear, acute, 1–1.5 cm. long. 23. *H. Kelloggiana*
  - Pod finely strigose.
    - Leaflets usually cuneate or oblong and retuse at the apex.
      - Pod 1–1.5 cm. long, slightly arcuate. 21. *H. tenera*
      - Pod about 3 cm. long or more, strongly arcuate. 25. *H. Rattani*
    - Leaflets linear, acute; pod about 2.5 cm. long, moderately arcuate. 24. *H. rattanoides*
- Calyx white-hairy.
  - Pod glabrous.
    - Leaflets retuse or truncate at the apex.
      - Pod about 5 mm. wide, arcuate at the base; corolla about 12 mm. long. 26. *H. Lindheimeri*
      - Pod about 3 mm. wide or less; corolla 10 mm. long or less.
        - Pod straight; corolla 10 mm. long. 27. *H. leptocarpa*

Pod more or less arcuate; corolla 5–8 mm. long.
Pod abruptly acute; plant green; stipules lanceolate or lance-subulate.
Calyx-teeth longer than the tube; pod 3 mm. broad, strongly arched at the base; plant erect or ascending. 28. *H. Nuttalliana*
Calyx-teeth shorter than the tube; pod 1.5–2 mm. wide, equally arched throughout; plant decumbent or prostrate. 29. *H. leptocarpoides*
Pod gradually acute, equally arched throughout; plant canescent, decumbent; stipules ovate. 30. *H. montereyensis*
Leaflets linear to oblong, acute or obtuse.
Corolla about 1 cm. long; plant green; pod 2.5–3 cm. long. 31. *H. macilenta*
Corolla 5–8 mm. long; plant canescent; pod 2 cm. long or less.
Pod completely 2-celled.
Leaflets 7–11, those of the lower leaves oval to oblong.
Pubescence appressed. 32. *H. Emoryana*
Pubescence spreading. 33 *H. Davisiana*
Leaflets 3–7, all linear or linear-oblanceolate. 34. *H. subuniflora*
Pod with only partial partition. 35. *H. imperfecta*
Pod strigose; inflorescence sub-capitate, 1–5-flowered.
Leaflets oval to linear, acute to rounded at the apex. 36. *H. austrina*
Leaflets of the lower leaves very short, cuneate, often retuse at the apex. 37. *H. pertenuis*

21. **Hamosa tenera** (A. Gray) Rydb. *Astragalus tener* A. Gray, Proc. Am. Acad. **6**: 206. 1864. The type was collected by Douglas, and first published as *Phaca astragalina* β by Hooker & Arnott. Torrey & Gray referred the specimens doubtfully to *A. leptocarpus*. When Gray described the species the fruit was unknown and he associated it with *A. Breweri*. He also thought that *A. Hypoglottis strigosa* Kellogg was the same. See under *H. Kelloggiana* below. Watson transferred the species to the section MICRANTHI and placed it after *A. atratus* and *A. obscurus*. Jones in his Revision described the pod of *A. tener* as being 'nigrescent when young.' If he had used the word 'canescent' he would have come much nearer for the hairs are

white or ash-colored. If he meant by 'nigrescent' inclined to turn black in drying, his statement may be considered correct, though ambiguous. *Astragalus pauperculus* Greene is apparently the same; so also *A. Titi* Eastwood.

CALIFORNIA: *Douglas; Kellogg & Harford 190; 192;* Los Angeles County, *Abrams 3251;* Solidad, *Jones 47, 3155;* Santa Monica, *Hasse,* in 1890; Contra Costa County, *Eastwood 3818;* Butte County, *Mrs. Bruce 2078;* San Luis Obispo County, *Summers 13;* Alameda, *Greene* in 1891; Oakland, *Brewer 2573;* San Diego, *Jones 3152.*

22. **Hamosa Bruceae** (M. E. Jones) Rydberg. *Astragalus tener Bruceae* M. E. Jones, Rev. Astrag. 268. 1923. This is related to *H. tenera,* but differs in the broader, usually cuneate leaflets, and the deeper more curved and glabrous pod.

CALIFORNIA: Butte County, *Mrs. Bruce 2430; Heller 11286;* Byron, *Biolette,* in 1892.

23. **Hamosa Kelloggiana** Rydb. sp. nov. *Astragalus Hypoglottis strigosa* Kellogg, Proc. Calif. Acad. **2**: 115. 1861. Slender annual; stem glabrous or sparingly strigose, 1–2 dm. high, branched at the base; leaves 5–6 cm. long, ascending; stipules lance-deltoid, about 3 mm. long; leaflets 5–13, those of the lower leaves oblong or cuneate, 1 cm. long or less, those of the other leaves linear, 1–2 cm. long, acute or obtuse, 1–2 mm. wide, strigose beneath; peduncles 4–6 cm. long; racemes very short, 4–7-flowered; bracts lanceolate, 1 mm. long; calyx black-hairy, the tube 2 mm. long, the teeth lance-subulate, 1.5 mm. long; corolla bluish-purple, striate, 8 mm. long, similar to that of *H. tenera;* pod about 1.5 cm. long, arcuate, lunate, glabrous, 3 mm. wide and 2.5 mm. thick, cordate in cross-section.

The species is related to the two preceeding on one hand, and to the next on the other. It differs from *H. tener* in the narrow leaflets and the more arched and more compressed glabrous pod, tapering gradually at both ends; from *H. Bruceae* in the narrow leaflets, the narrower and not mottled pod, and the more numerous flowers; and from *H. rattanoides* in the shorter and glabrous pod. It is evidently the same as the plant described (at least mainly so) and figured by Kellogg as *Astragalus Hypoglottis strigosa.* His illustration consists of the drawing of a whole plant and a single leaf. The whole plant evidently illustrates this plant and he describes the pod as glabrous. The leaf resembles that of *H. tenera* the leaflets being linear-cuneate and slightly retuse as in *H. tenera*. In his descriptions he states that individuals are found either with linear or cuneate leaflets or with both. The leaf-form may not be constant, though I have not seen any evidence that it is not. At any rate the pod is not that of the typical *H. tenera* but nearer to that of *H. Bruceae*. Sheldon adopted the name *strigosus* as specific, following the Madison amendment of the Rochester Code, but applied it to *H. tenera*.

CALIFORNIA: Vallejo May 15, 1874, *Greene* (type in Gray Herbarium); Alameda County *Michener & Bioletti*, in 1891; Contra Costa County; *Eastwood 3818;* Oakland, *Holder 2573;* Mt. Diabolo, *Gibbons*, in 1872; *Kellogg & Hartford 192;* San Francisco, *Vasey*, in 1875; Alviso, *Williamson*.

24. **Hamosa rattanoides** (M. E. Jones) Rydb. *Astragalus tener rattanoides* M. E. Jones, Rev. Astrag. 269. 1923. This is related to *H. Rattani* differing in the longer pubescent pod and stands in the same relation to it as *A. Kelloggiana* does to *A. Brucei*. The following specimens are recorded:

CALIFORNIA: Mount Eden, *Brandegee* (type); Woodland, *Blankinship*, May 20 and April 8 (mainly) 1893); Contra Costa County, *H. Edwards*, in 1895; without locality, *Bridges 77;* Aloiso, *R. J. Smith*, in 1915; Vaccaville, *Jepson*, in 1892.

25. **Hamosa Rattani** (A. Gray) Rydb. *Astragalus Rattani* A. Gray. Proc. Am. Acad. **19:** 75. 1883. This differs from *H. tenera* in the more robust habit, usually broader leaflets and the long pod, 3–4 cm. long, strongly arched, very narrow, and gradually tapering at each end. *A. clarianus* Jepson seems to be the same. The type of *A. clarianus* has not been seen by me, but Jeppson's description and illustration fits *H. Rattani* as I understand it and as described and figured by Jones.

CALIFORNIA: Sacramento River, Butte County, *Mrs. Bruce 2432;* Humboldt County, *Rattan*, in 1883; *Goodard 6124;* Mendocino County, *Rattan 10; Purpus*, in 1889; *Blankinship* in 1893; Yolo Co., *Ferris 706;* Humboldt Co., *Tracy 4241*.

26. HAMOSA LINDHEIMERI (A. Gray) Rydb. This differs from the rest of the annual species of *Hamosa* by its large flowers, broad glabrous pod, and stouter habit. Jones (Rev. Astrag. 267. 1923) claims, for what reason I do not know, that *Astragalus recticarpus* Wood (Bot. Gaz. **3:** 50. Je 1878) is the same. Wood's description does not fit it. Furthermore Wood himself (Bot.

Gaz. **3**: 70. Au 1878) two months later made the following correction: '*Astragalus recticarpus*. This plant is a form of *Indigofera leptosepala* Nutt., with very narrow leaflets.'

TEXAS: *Wright*, in 1850; Brown County, *Reverchon* [Curtiss No.] *601**; Northwestern plains, *Pringle*, in 1883; San Antonio, *Thurber*, in 1853; New Braunfels, *Lindheimer 258, 442, 746, 747;* without locality, *Hayes, Nealey 91;* Dawson, *Reverchon 3761; Young*, in 1914; Galveston, *Tracy 9104, 9111;* Austin, *E. Hall 148*, in part; without locality, *Pope, Bray 449, Wright, Thurber, Young 41;* Minerva, *Reverchon 3759;* Brown Co., *239*.

27. HAMOSA LEPTOCARPA (T. & G.) Rydb. This resembles *H. Nuttallii* closely, but the pod is straight, the flowers are larger and the inflorescence is more distinctly racemose.

TEXAS: Without locality, *Drummond I;* Rio Brazos, *Drummond*, in 1850; Sabine River, *Leavenworth;* Galveston, *E. Meyer;* Dallas County, *Reverchon* (Curtiss No.) *601**, 241;* Nueces County, *Heller 1443;* Tarrant County, *Ruth 356;* Corpus Cristi, *Tracy 9104;* Eagle Pass, *Hanson 366;* Marshall, *Earle 5;* Seely, *Plank*, in 1894; Tyler County, *Nealey 26;* Hempstead, *E. Hall 147;* San Marcos, *Stanfield*, in 1897; locality not recorded, *Lindheimer 46; Reverchon 1637; Berlandier 361; Havard 181, 182;* Galveston, *Tracy 9111;* Bastrop, *Tharp 828;* Industry, *Wurzlow 32*, in part; Brazos, *Nealley 70*.—ARKANSAS: *Leavenworth*.—OKLAHOMA: Wervoka, *Carleton 101*.

28. HAMOSA NUTTALLIANA (DC) Rydb. was based on *Astragalus Nuttallianus* DC., a substitute for the untenable *A. micranthus* Nutt. The type of the latter was collected on the Red River, Arkansas, and was described as having glabrous pod and emarginate leaflets. It is evident that Jones had misinterpreted this species as he describes the pod as 'pubescent except when fully ripe at times' and gives the distribution as 'common on the Pacific Coast to the plains of Colorado throughout the Great Basin and southward to central Mexico.' This would apply better to *Hamosa austrina* Small. His varieties *A. Nuttallianus enneajugus* and *A. Nuttallii quadrilateralis* represent the true *H. Nuttallii*. The former is merely a more luxuriant form; the latter is practically the same, only that the pods are well mature, more turgid and more or less 4-angled; a similar plant was collected by Dr. Leavenworth near Fort Towson,

Arkansas. Only one specimen of *H. Nuttalliana* has been seen from the west side of the continental divide, namely one collected by Crandall in 1898, at Palisades, Delta County, Colorado. The distribution of the species is limited to Oklahoma, Texas and western Arkansas.

29. **Hamosa leptocarpoides** (M. E. Jones) Rydb. sp. nov. *Astragalus Nuttallianus leptocarpoides* M. E. Jones, Contr. W. Bot. 8: 22. 1898. This resembles a small *H. Nuttalliana*, but the pod is more slender, and evenly but slightly curved throughout (not as in *H. Nuttalliana* more strongly curved near the base) and in the shorter calyx-lobes. In this respect it resembles more *H. leptocarpa*, but the flowers are much smaller, and the pod arcuate. The only specimens seen are those of the type collection, collected by Engelmann on Galveston Island (Mo. Bot. Gard.).

30. **Hamosa montereyensis** Rydb. sp. nov. Annual; stem branched at the base, decumbent, strigose, 1–2 cm. long; leaves 2–3 cm. long, spreading; stipules ovate, about 4 mm. long, ciliate; leaflets 13–19, oblong, 4–7 mm. long, about 2 mm. wide, emarginate or truncate at the apex, cuneate at the base, glabrous above, grayish-strigose beneath, rather thick; peduncle 3–5 cm. long; racemes very short, 4–8-flowered; bracts lanceolate, 1–2 mm. long; calyx strigose, the tube 2 mm. long; teeth lance-subulate, 2 mm. long; corolla purplish, 7–8 mm. long; banner broadly obovate, notched at the apex; wings about as long, the blade broadly oblanceolate, obtuse, with a reflexed auricle; keel-petals shorter, broadly lunate, abruptly incurved at the obtuse apex; pod glabrous, slightly and evenly arcuate, acute at each end, 1–1.5 cm. long, 3 mm. wide.

This is related to *H. Nuttalliana* but is spreading on the ground, more canescent, with short leaves and thick leaflets, and different pods.

The type was collected at Monterey, Nuevo León, February 1880, *Palmer 237* (Gray Herbarium).

31. HAMOSA MACILENTA Small is related to *H. leptocarpa* and *H. Nuttalliana*, but differs from both in the non-retuse leaflets. The corolla is as large as that of the former, and the raceme more or less elongate, but the pod is distinctly arcuate below, as in *H. Nuttalliana*. Jones has reported specimens hybrid between the two, but I do not think it is of hybrid origin. Jones regarded this as a synonym of *Astragalus leptocarpus*.

TEXAS: Blanco River, *Wright;* without given locality, *Reverchon 1637; Mexican Boundary Survey 254a;* Gillepie County, *Jermy 263.—Nuevo León:* Monterey, *Canby 77.*—COAHUILA: Diaz, Rio Grand Valley, *Pringle 9026.*

32. **Hamosa Emoryana** Rydb. n. sp. *Astragalus Nuttallianus* var. [no. 1.] A. Gray, Pl. Wright. **2**: 43. 1853. This species was first collected by C. Wright in 1850 (no. *156*) and Dr. Gray gave a short description (see Pl. Wright. **1**: 52. 1852). As this number represents a depauperate form, I have not made it the type. The same form was also collected by Wright in 1852 (no. *1001*, in part, the other part being depauperate specimens of *H. austrina*). In both the Gray Herbarium and the Torrey Herbarium the specimens are mounted on the same sheet. Gray in Plantae Wrightianae **2**: 43 gives five localities, and the two sets might not have been collected at the same locality. Wright also collected well developed specimens the same year at El Paso (no. *1359*). This number as represented in the Torrey Herbarium I have taken as the type. Gray in his description indicates that some of the specimens have hairy and some glabrous fruit. In the Torrey Herbarium only glabrous-fruited specimens are represented.

Astragalus Nuttallianus canescens T. & G. might be the same. Where this name was first mentioned in print (Pacific R. R. Rep. **2**: 163. 1855) there was no description, only a reference to 'Gray Pl. Wright.,' without page or specimen number. This may refer to four of Wright's numbers, viz. *156*, *1359*, *1001*, and *1360*, all of which have a short description.

Parry (Am. Nat. **9**: 270. 1875) simply enumerated *A. Nuttallianus canescens.* His specimen no. *50* represents *A. austrina* Small. So does *Wright 1001* and *1360* in part. The name *A. Nuttallianus canescens* should therefore be cited to S. Watson's Bibl. Index 198, 1878, as the author refers back to the published but nameless description in Plantae Wrightianae both in volume 1 and volume 2. As Watson admits the var. *trichocarpus*, it may be inferred that the var. *canescens* should apply to the glabrous fruited plant, but technically it refers to both, and the name *canescens* is preoccupied as specific in the genus *Astragalus* and therefore it is best not to use it in *Hamosa.*

Hamosa Emoryana has been confused with *H. Nuttalliana, H. macilenta* and *H. austrina.* From the first it differs in the leaflets, which are shorter, hairy on both sides, never emarginate, and by the pod which is more arched. It has the leaf-form of *H. macilenta*, though the leaflets are smaller, but is distinguished by the other characters and by the much smaller flowers. It is harder to distinguish it from *H. austrina* (*A. Nuttalianus trichocarpus*), the main difference being the glabrous fruit, which is usually more curved; the leaflets are usually shorter. The following specimens belong here:

TEXAS: El Paso, *Vasey*, in 1881; *E. Hall*, in 1872; *Wright 1359. 1001*, in part (depauperate); Frontera and Eagle Pass, *Mexican Boundary Survey 288*, in part; Sommerville, *Reverchon* (Curtis no.) *601**;* west of Pecos, *Tracy & Earle 418;* Shafton, *Hanson 557;* Davis Mountains, *Earle & Tracy 190;* Bracket, *Canby 74;* Tom Green Co., *Tweedy 61;* Cow House Creek, *Reverchon 1368.*—NEW MEXICO: *Wright 156;* Capitan, *Earle 632;* Tunitcha Mountains, *Standley 7835;* Organ Mountains, *Wooton*, in 1903 and 1905.—ARIZONA: Tucson, *Griffiths 2408, 3479; Toumey*, in 1894, 1895, and 1896; Red Rock, *W. F. Parish* in 1884; without locality, *Palmer 507;* Kayenta, *Wetherill;* Tucson, *Harris 1428;* Carrizo Mountains, *Standley 7461;* Verde River, *Smart 93.*—CALIFORNIA: Paraminth Mountains; *Coville & Funston 513.*—CHIHUAHUA: near the City, *Palmer 171*, in 1908; *Pringle 276*, in 1885.

33. **Hamosa Davisiana** (Greene) Rydb. sp. nov. *Astragalus Davisianus* Greene, Ms. in herb. Annual or perhaps perennial; stem branched at the base, decumbent, 1–1.5 dm. long, terete, hoary-canescent; leaves 2–3 cm. long, spreading; stipules ovate, acuminate, 4 mm. long; leaflets 11–15, oval or elliptic, 2–5 mm. long, hoary-canescent with ascending or spreading hairs; peduncles 1–3 cm. long; bracts lance-subulate about 2 mm. long; calyx hirsute, the tube 2 mm. long, the teeth subulate, nearly as long; corolla apparently white, 7–8 mm. long, similar to that of *H. Nuttalliana;* pod regularly arcuate, 12–18 mm. long, 2.5 mm. wide and thick, glabrous, strongly reticulate, obcordate in cross-section.

This species is related to *H. Emoryana* but distinguished by the hoary loose pubescence and the strongly reticulate pod. The type was collected in the Davis Mountains, Texas, April 28, 1902, *Tracy & Earle 329.* (Herb. N. Y. Bot. Gard.)

34. **Hamosa subuniflora** (Greene) Rydb. *Astragalus subuniflorus* Greene, Leaflets **2:** 42. 1910. This is closely related to

the preceding, differing in the fewer (5–9), longer, and narrower leaflets and few- (1–3-) flowered racemes. The corollas are apparently white. It is known only from Tehuican, Puebla, *Pringle 6678* (type); *Arsène 3622*.

35. **Hamosa imperfecta** Rydberg, sp. nov. Annual; stem branched at the base, decumbent, 2–3 dm. long, very sparingly strigose, straw-colored, terete; leaves 2–4 cm. long; stipules lanceolate, 2 mm. long; leaflets lance-oblong or lance-linear, acute at each end, strigose beneath, glabrate above, 5–10 mm. long; peduncles 3–8 cm. long; racemes usually 2-flowered; bract subulate, 1 mm. long; calyx strigose, often partly with black hairs; the tube less than 2 mm. long, the teeth subulate, of about the same length; corolla apparently white, 5 mm. long; pod arcuate especially at the base, glabrous, 15–18 mm. long, 2 mm. broad, and 3 mm. deep, slightly sulcate on the lower suture, only partially 2-celled, the partition very narrow; seeds 2.5 mm. long.

This resembles a slender *H. Emoryana* but the pod is imperfectly 2-celled and the calyx often bear black hairs.

NEVADA: Rhyolite, Nye County, May 17, 1909, *Heller 9637*, (type, herb. N. Y. Bot. Gard.).—ARIZONA: Yucca, *M. E. Jones*, in 1887.—LOWER CALIFORNIA: Rosario, *Orcutt 1349*.

36. HAMOSA AUSTRINA Small. This was first collected by Drummond in Texas and described by Torrey and Gray as *Astragalus Nuttallianus trichocarpus*. Young in her Flora of Texas raised it to specific rank, but evidently confused it partly with *H. Emoryana*, as she described it as having glabrous fruit. The name *Astragalus trichocarpus* was preoccupied by *A. trichocarpus* Wallich of 1868. Small independently described the plant as *H. austrina*, the type being *Thurber 417* from Rio Fronteras. On the type sheet the name of the state is not give. As there was at the time of the Mexican Boundary Survey a Frontera above El Paso in Texas, Dr. Small presumed that it was from there. A duplicate of *Thurber 417*, however, gives the locality as Fronteras, Sonora, Mexico. The plant is very common in Texas and Arizona but the range extends from Oklahoma to Utah, Lower California and Durango.

37. **Hamosa pertenuis** (Greene) Rydb. *Astragalus pertenuis* Greene, Leaflets **2**: 42. 1910. This is related to *H. austrina*, having the hairy pod (though smaller and often imperfectly 2-celled) of that species, but it is much more slender, decumbent, and the leaflets of the basal leaves are decidedly cuneate and

deeply notched. It was first described by Vasey & Rose (Contr. U. S. Nat. Herb. 1: 15. 1893) as *Astragalus* sp., stating that they had distributed it under the name *A. cedrocensis* but that "Mr. Watson thinks it is *A. Nuttallanus.*" Jones made it a variety of *A. Nuttallianus.* The latter described the pods as "smooth." In all specimens seen they are strigulose and reticulate.

LOWER CALIFORNIA: Cedros Island, *Palmer 692;* Los Angeles Bay, *Palmer 571;* San Jorge, *Brandegee,* in 1889; 'northern Lower California,' *Orcutt,* in 1886; Cape Region, *Brandegee,* in 1892.—CALIFORNIA: Goffs, San Bernadino Co., *Parish 9656.*

6. ACUTIROSTRES

This group consists of two species, which have been referred to *Oxytropis* or *Aragallus.* Notwithstanding the fact that the keel is produced into a short beak, they evidently do not belong to that genus, but are in all other respects good species of *Hamosa.* There are several species of *Homalobus* and *Hamosa* in which the keel is acute. In the present two species it is acuminate, but the beak is not porrect as in most species of *Aragallus.*

Calyx-lobes much shorter than the tube; leaflets not retuse.	38. *H. nothoxys*
Calyx-lobes equaling or longer than the tube; leaflets retuse.	39. *H. acutirostris*

38. **Hamosa nothoxys** (A. Gray) Rydb. *Astragalus nothoxys* A. Gray, Proc. Am. Acad. 6: 232. 1864. This is evidently related to *H. arizonica, H. Coahuilae,* and *H. bernadina,* differing (besides the beak) in the leaflets, which are glabrous above and broader; the pod is nearly erect but longer than in *H. Coahuilae.* The plant was originally described as an annual and evidently blooms the first year, but some specimens as for instance those collected by Pringle in the Santa Catalina Mountains are without doubt perennial.

ARIZONA: Tucson Range, *Griffiths 2541;* Sabinio Cañon, *Griffiths 2581;* Apache Pass, *Greene 1072,* in part (fruit); Santa Catalina Mountains, *Pringle,* in 1881; Patagonia Mountains, *Tidestrom 776;* Santa Rita Mountains, *808.*—SONORA: *Thurber,* in 1851; San Luis Mountains and Guadaloupe Canon, *E. K. Smith.*—CHIHIAHUA: Puerta di San Diego, *Hartman 622, 630.*

39. **Hamosa acutirostris** (S. Wats.) Rydb. *Astragalus acutirostris* S. Wats. Proc. Am. Acad. **20**: 360. 1885. Notwithstanding the beaked keel, this species is a true *Hamosa* related to the LEPTOCARPAE. Greene redescribed this species under the name of *Astragalus streptopus*. Jones has transferred it to *Oxytropis* and Heller to *Aragallus*, on account of the beaked keel.

The general habit is somewhat like that of *H. Nuttallianus*, the leaflets being retuse as in that species, but the racemes is more elongate, the calyx has some black hairs, the pods are more acute at each end and strigulose and the pubescence of the leaves is more spreading.

CALIFORNIA: Mojave Desert, *Curran*, in 1884, *Parish 1276*, *Lemmon*, in 1884, Darwin, *Jones*.

7. HARTWEGIANAE

The group is characterized by a dense raceme of usually many small flowers. The pod is small, short and rather broad, more or less triquetrous, inverted V-shaped and Y-shaped in cross-section, lanceolate and gradually acute in outline.

Plants about 3 dm. high, erect; raceme elongate.	
Corolla purple, 7–8 mm. long.	40. *H. militaris*
Corolla white or ochroleucous.	
Pod pubescent.	
Calyx black-hairy.	
Pod 7–9 mm. long, strigose.	
Pod black-hairy; leaflets linear.	41. *H. Saltonis*
Pod white-hairy; leaflets oblong.	42. *H. Goldmani*
Pod about 1 cm. long, strigulose.	43. *H. hidalgensis*
Calyx white-hairy; pod 10–12 mm. long.	
Corolla 7–8 mm. long.	44. *H. Hartwegii*
Corolla 4–5 mm. long.	45. *H. vaccarum*
Pod glabrous.	
Corolla pink-purple.	48. *H. Esperanzae*
Corolla white.	46. *H. Clevelandi*
Plant 1–2 dm. high, decumbent at the base.	
Plant silvery canescent; raceme elongate.	47. *H. hypoleuca*
Plant merely strigose, the leaves glabrate above, raceme short.	
Corolla less than 1 cm. long; pod lance-oblong.	
Pod glabrous; corolla 8 mm. long, pink-purple.	48. *H. Esperanzae*
Pod strigose.	
Leaflets linear.	
Calyx white-hairy, the teeth shorter than the tube.	49. *H. parva*

Calyx black-hairy, the teeth fully equaling the tube.	50. *H. asprella*
Leaflets obovate.	51. *H. hypoxyla*
Corolla more than 1 cm. long, white; plant densely cespitose, prostrate; pod broadly oblong.	52. *H. Pringlei*

40. **Hamosa militaris** (M. E. Jones) Rydb. *Astragalus militaris* M. E. Jones, Rev. Astrag. 278. 1923. Jones in describing this species evidently had a mixture before him. In his key he described the pod as being 'smooth.' By 'smooth,' he evidently meant glabrous, for he contrasted 'smooth' against 'loosely pubescent' in *A. Hartwegii* and 'nigrescent' (meaning having a tendency to be black-hairy) in *A. Saltonis.* The type of *A. militaris* in Jones herbarium (now at Pomona College) has strigulose pods. He also cited two numbers, *Pringle 1586* and *Palmer 441.* The character 'pod smooth' might have been taken from the former, which is not at hand at present, but apparently belongs to *H. esperanzae. Palmer 441* belongs to *H. Goldmani* and has strigulose pod. *H. militaris* is related to *H. Hartwegii*, differing in the purple corolla and the strigulose pod, the hairs being much shorter.

CHIHUAHUA: Soldier Canyon, *Jones*, in 1903 (type); Colonia Diaz, *E. W. Nelson 6448.*—SAN LUIS PATOSI: Media Luna, *Palmer 65* and *81*, Guascana, *Purpus 5195.*

41. **Hamosa Saltonis** (M. E. Jones) Rydb. *Astragalus Saltonis* M. E. Jones, Rev. Astrag. 279. 1923. The species was described from specimens collected at Salto de Aqua, State of Mexico, *Purpus 1751.* As I understand the species, it is closely related to *H. Hartwegii*, differing in the black-hairy calyx, the shorter and plumper, less arcuate, and black-hairy pod.

PUEBLA: Rancho Pasado, near the city of Puebla, *Nicolas 105* (distributed by Arsène). Mayorazzo, *Arsène 1429;* San Juan, *207.*—HIDALGO: Pachuca, *Rose, Painter & Rose 8811.*—MEXICO (State and Federal District): *Rose & Painter 7290;* Tacubaya, *Bourgeau 337;* Mixode, *Arsène 10018.*

42. **Hamosa Goldmani** (M. E. Jones) Rydb. *Astragalus Goldmani* M. E. Jones, Rev. Astrag. 281. 1923. This species is more closely related to *H. vaccarum*, differing in the black-hairy calyx, and the shorter and plumper pod.

CHIHUAHUA: Parral, *Goldman 119* (type); Guerrero, *Pringle*

1217 (?, with longer pod).—DURANGO; Ramos, *E. W. Nelson 4708;* Santiago Papasquiaro, *Palmer 441*, in part; Otinapa, *Palmer 395*.

43. **Hamosa hidalgensis** Rydb. sp. nov. Perennial; stem 4–6 dm. high, striate, glabrous or minutely strigulose; leaves 6–10 cm. long, spreading; stipules deltoid, 3–4 mm. long, distinct; leaflets 21–29, oblong, 10–20 mm. long, 2–4 mm. wide, glabrous above, strigulose beneath, truncate, rounded, or, retuse at the apex; raceme 10–15 cm. long; rachis black-hairy; bracts lanceolate, 2 mm. long; flowers reflexed; calyx black-hairy, the tube 2 mm. long, the teeth lanceolate, 1 mm. long; corolla white, about 6 mm. long; banner obovate, strongly arcuate, retuse at the apex; wings somewhat shorter, the blade broadly elliptic; wing-petals still shorter, the blade broadly lunate, rounded at the apex; pod linear-oblong, arcuate, about 12 mm. long, 4 mm. wide, and 2.5 mm. thick, acute at each end, minutely strigulose, broadly cordate in cross-section.

This is closely related to *H. Hartwegii*, but differs in the smaller corolla, and very short pubescence, which is black on the flower-rachis and calyx. Type *Pringle 9720* (herb. N. Y. Bot. Gard.) was collected at Dublan, Hidalgo, September 19, 1902. Besides this *Rose 2757* from Jacatecas may be referred here.

44. **Hamosa Hartwegii** (Benth.) Rydb. *Astragalus Hartwegii* Benth. Pl. Hart W. 10. 1839. The type of *Astragalus Hartwegii* came from Aguascalientes. It is the most widely distributed species of the group. Jones describes the calyx as being 'nigrescent,' an expression which is rather ambiguous. The original meaning is 'growing black' but it is often used as 'inclined to be blackish,' whether it applies to the calyx itself or its hairs. In related species he has evidently used the expression as referring to the hairs. Neither in a duplicate of the type in the Gray Herbarium, nor in most of the specimens regarded by the writer as typical, there is any trace of black hairs either on the calyx or the fruit. In these the hairs on both are white and rather loose. The corolla in the type was apparently white or ochroleucous (so described in the original) and about 7 mm. long.

AGUASCALIENTES: *Hartweg 53*.—HIDALGO: *Rose & Painter 8306*.—MEXICO (Federal District): San Barja, *Arsène 10090;* Guadalupe, *Bourgeau 483*.—DURANGO: Near the City, *Palmer 290;* Tepehuanes, *Palmer 278*.—CHIHUAHUA: Santa Eulalia Mountains, *Pringle 528;* Bolson de Mapimi, *Gregg;* Guerrero, *Pringle 1217.*—COAHULA: San Lorenzo de Laguna, *Palmer 235.*—SONORA: El Padrero, *Schott;* Los Nogales, *E. K. Smith.*

45. **Hamosa vaccarum** (A. Gray) Rydb. *Astragalus vaccarum* A. Gray Pl. Wright. **2**: 43. 1853. This is closely related to the preceding, differing in the smaller ochroleucous corolla and narrower pod; it maybe not distinct.

NEW MEXICO: Ojo de Vaca, *Wright 1002* (type); *Thurber 1051.*—ARIZONA: Huachuca Mountains, *Lemmon 2658.*—DURANGO: Santiago Papasquiaro, *Palmer 441,* in part;—CHIHUAHUA; *E. W. Nelson, 4828.*

46. **Hamosa Clevelandi** (Greene) Rydb. *Astragalus Clevelandi* Greene, Bull. Torrey Club. **9**: 121. 1882. This resembles closely *H. vaccarum,* differing mainly in the glabrous pod. The type came from Lake County, California, collected by Cleveland.

CALIFORNIA: Mount St. Helena, Napa County; Greene in 1883; Hot Springs, Lake County, *Abrams 6269.*

47. **Hamosa hypoleuca** (Schauer) Rydb. *Astragalus hypoleucus* Schauer, Linnaea **20**: 747. 1847. This species is also related to *H. Hartwegii,* but is a much lower plant, rarely 2 dm. high; it differs mainly from all the preceding species of the group by its silvery pubescence, which extends to both surfaces of the leaflets. Sometimes in depauperate specimens the leaflets are broader and the raceme shorter; this is the case with *Purpus 2477,* which Jones has referred to *A. hypoxylus* S. Wats. The type came from the mountains of Mexico, the locality not indicated. *Ashenborn 343.*

The type of *Astragalus Luisanus, Purpus 3208,* as represented in the National Herbarium, was first determined by Jones as *A. parvus* Hemsley, but afterwards made the type of his new species (see Rev. Astrag. p. 275). It belongs to *H. hypoluca.* On the same page he cited *Purpus 2477* as one of his 'types' of *Astragalus Luisanus,* and on page 278 the same number under *A. hypoxylus.* I have seen three sheets of this number and all are referable to *H. hypoleuca.*

HIDALGO: Tula, *Pringle 6366;* El Salto, *Pringle 9721; Rose & Painter 7089.*—MEXICO: Tultenango, *Rose & Hay 5428;* Paturage a Zapan, *Bourgeau.*—PUEBLA: Puebla, *Arsène & Amable 2020;* Esperanza, *Purpus 2477;* San Luis Tultitlanapa, *3208;* Tepeara, *Rose & Hough 4713;* Chalchicomula, *Pringle 9648.*—COAHUILA:

45 miles east of Saltillo, *Palmer*, in 1880; Buena vista, *Gregg*, in 1848.—QUERETARO: *Arsène 10372, 10574, 10512; Rose, Painter & Rose 9584.*

48. **Hamosa Esperanzae** (M. E. Jones) Rydb. *Astragalus Experanzae* M. E. Jones, Rev. Astrag. 277. 1923. *Astragalus Chapalensis* M. E. Jones, *loc. cit.* The type came from Esperanza, Publa, *Purpus 3207*. The type of *A. Chapalensis*, collected in fruit only, can not be distinguished by the characters given by Mr. Jones. *Palmer 203*, referred by him to *A. Esperanzae*, has as narrow stipules as the type of *A. Chapalensis.*

SAN LUIS POTOSI: Alvarez, *Palmer 203*.—HIDALGO: Pachuca, *Pringle 7644; 6955*.—JALISCO: Chapala, *Rose & Painter 7627*.—CHIHUAHUA: Carretas, *Pringle 1586* (?).

49. **Hamosa parva** (Hensley) Rydb. *Astragalus parvus* Hemsley, Biol. Cent. Am. Bot. **1**: 266. 1880. *Astragalus Schaffneri* M. E. Jones, Rev. Astrag. 276. 1923. Notwithstanding the fact that Jones remarks under *A. Schaffneri*, 'This has been referred to *A. parvus* by Watson, but it appears to be quite a different plant,' the writer believes the two identical. In the Columbia College herbarium there is a duplicate of the type of *A. parvus*, *Parry & Palmer 174* and in the herbarium of the New York Botanical Garden there is one of *A. Schaffneri*, viz. *Schaffner 611–815;* the two evidently represent the same plant. Both came from the valley of San Luis Potosi.

50. **Hamosa asperula** Rydberg sp. nov. A cespitose perennial, with a woody root and caudex; stems decumbent or spreading, 1–2 dm. long, purplish, appressed-pubescent with short stiff hairs; leaves 3–5 cm. long, spreading, the rachis pubescent, sulcate on the upper side; stipules connate, deltoid, acuminate, membranous; leaflets 13–23, linear, 6–12 mm. long, glabrous above, strigose beneath, more or less involute; peduncles 3–6 cm. long; racemes dense, 1–3 cm. long; bracts lanceolate, membranous, 2–3 mm. long; pedicels 1 mm. long; calyx black-hairy, the tube 2.5 mm. long, campanulate, the teeth subulate, 2.5 mm. long; corolla purplish, 8 mm. long; banner obovate, strongly arcuate, wings nearly as long, the blades broadly obovate; keel-petals shorter, broadly lunate, the blade nearly semiorbicular, obtuse; pod falcate, strigose, 14–16 mm. long, 2–6 mm. broad and high, tapering at the apex.

The type was named *Astragalus Esperanzae* by M. E. Jones, but differs in the narrow leaflets and the narrower and pubescent pod. It was collected between Pachuca and Real del Monte, Hidalgo, Aug. 31, 1903, *Rose & Painter 6679* (U. S. Nat. Herb. no. *450235*).

51. **Hamosa hypoxyla** (S. Wats.) Rydb. *Astragalus hypoxylus* S. Wats. Proc. Am. Acad. **18:** 182. 1883.

Dr. Watson thought that it was related to *A. Cobrensis* and *A. arizonicus.* It is not at all related to the former, and only remotely so to the latter. Sheldon included it in his section EREMITICUS, and Jones placed it in MICRANTHI, together with *A. parvus* and other related Mexican species. The affinity is evidently with these, but Jones MICRANTHI is too heterogenous, and this name belongs to *A. Nuttallianus* and related species.

52. **Hamosa Pringlei** (S. Wats.) Rydb. *Astragalus Pringlei* S. Wats. Am. Acad. **21:** 449. 1886. This species is in habit quite unlike the rest, being densely cespitose, with numerous prostrate short stems and large flowers.

CHIHUAHUA: Near the City, *Pringle 79,* in 1885; *Palmer 89.*—DURANGO: Tepehuanes, *Palmer 18.*

Jones included in this group the following species, which are either doubtful or belong to other genera or sections: *A. lentiformis* and *A. Lemmoni,* in which the pod has both margins acute; *A. Madrensis, A. ervoides,* of doubtful relationship; *A. Greggei,* which belongs to the section TRICARINATA; *A. Pueblae,* which has a 1-celled pod, and should be referred to *Phaca; A. oxyrhynchus,* which is a *Hesperastragalus; A. Seatoni* and *A. Purpusi,* which apparently are species of *Atelephragma.*

Commelinantia Pringlei

B. C. THARP

(WITH PLATES 26, 27)

In a former paper,[1] describing the genus *Commelinantia* and re-assigning the species originally described as *Tradescantia anomala*[2] Torrey to the new genus, mention was made of the likelihood that *Tradescantia Pringlei* S. Wats.[3] should also be assigned to *Commelinantia*. At that time scarcity of material prevented a sufficiently detailed examination to warrant more than a suggestion of the probable relationship. In March, 1923, opportunity was afforded me to collect and examine an abundance of fresh material near Monterrey, Mexico, the type locality of the species. In addition to collecting much material for drying, I brought back living plants, which were planted in the open until winter; then some were transferred to the greenhouse, and these have been growing alternately in the open and in the greenhouse, to insure our not losing them. Examination of fresh material of the original collection and continual observation during the three years we have had it growing at Austin has confirmed my earlier suspicion and seems beyond question to warrant the inclusion of this species in the genus *Commelinantia*.

Material was collected on March 9, 1923, on Topo, a low mountain arising out of the valley four or five miles to the northeast of Monterrey. The plant is invariably found on steep northeast or north slopes where it is protected from the intense light and heat which cause the south and west slopes to be dry and arid. In altitude, on Topo, it ranged from near the base to near the top—probably from 1800 to 3000 feet. On March 10 it was again collected, and in more advanced condition, in a range of mountains some twelve miles to the south of Monterrey in the vicinity of one of the Mexican Lead Company's mines. Its altitude there ranged from 2500 to 4500 feet. We climbed to an estimated altitude of at least 5000 feet and apparently passed the higher limit of the species in that vicinity. Time, however, would not permit a search of sufficient intensity to warrant this statement as unquestionably certain.

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[1] Bull. Torrey Bot. Club **49**: 269–275. *pl. 10, 11.* Sept. 22, 1922.

[2] U. S. and Mex. Bound. Bot. 225. 1859.

[3] Trans. Am. Acad. **26**: 157. 1891.

The plant is beyond doubt a perennial. Instead of the aerial normal inflorescence being strictly terminal, as in the case of *C. anomala*, it is strictly a simple axillary peduncled scorpoid raceme, the peduncle differing from vegetative branches in that it does not break through the leaf sheath, even in the lowermost flowering bracts whose sheaths are 4–5 mm. high. The upper bracts have successively shorter sheaths, the uppermost being sheathless. The racemes are fewer-flowered, never more than 5, and no peduncle ever has been observed to produce more than a single seed pod. This pod develops from the first flower to bloom, those which come later falling off. The calyx is essentially similar to that of *C. anomala* except that the sepals are smaller and the veins are more prominent and are slightly reticulated. The petals, however, are equal in size and alike in color, being slightly more decidedly lavender than are those of *C. anomala*. The stamens correspond essentially to those of *C. anomala*, though there is less difference between the posterior and postero-lateral stamens than in the corresponding stamens of *C. anomala*, and the pubescence of the anterolateral filaments is less dense.

A very interesting feature of the plant is the cleistogamous flowers, a feature shared, so far as I can find, by only one other species (*Commelina banghalensis*) of the family, and rare in all monocotyledons. These cleistogamous flowers are usually singly disposed at the ends of true, though modified, branches which invariably break through the sheaths of the lowermost leaves, grow out laterally for several centimeters, then turn abruptly downward, always at a node, carrying the flower below the surface of the soil and developing the fruit in this protected situation. The branches also arise abundantly from nodes beneath the soil surface and spread laterally. The appearance of these flowers is similar to that of the normal ones, except they are smaller, the sepals have no green color, and of course they do not open. Leaves on the filiform branches are usually from one to three in number and are almost or quite reduced to sheaths. The length of these branches is usually determined by the distance of the point of origin above the surface of the soil, except where this point is itself below the surface, in which case the branch extends horizontally for an indefinite though usually short distance of a few centimeters.

In addition to its elaborate floral provision for reproduction, the plant also propagates vegetatively by means of short rhizomes. It is not uncommon to find clusters of stems apparently representing separate plants thus connected beneath the soil surface. All vegetative parts are succulent and brittle, in this respect resembling the "inch plant" or "Wandering Jew" of window boxes. *C. pringlei* further resembles this plant in the ease with which it may be grown from cuttings.

In view of the clarifying effect of this study of fresh material upon certain more or less conjectured points by means of which the generic description of my other paper sought to provide for this species, it has become necessary to amend that description slightly, to include perennial as well as annual plants, and since *C. Pringlei* has no basal leaves, to omit reference to this point in the generic description.

COMMELINANTIA PRINGLEI (S. Wats) Tharp, Torreya **24:** 52. 1924. Perennial, pea green; *stems* clustered weakly, erect or ascending, finally much branched; *basal leaves* wanting; *lower cauline leaves* reduced to sheaths below soil surface, gradually increasing in size upward, orbicular, abruptly acuminate, sessile or nearly so at the tops of sheaths which are 1 cm. high or less; *upper cauline leaves* increasing in size with increase in height upon the stem, broadly lanceolate, the blades 10 cm. long or less, purplish underneath, abruptly narrowed into short petioles which surmount sheaths about 1 cm. high; peduncle very slender, 1.5–6.0 cm. long; *raceme* simple, the bracts orbicular, obtuse, green with purplish margins, 1–1.2 mm. in diameter; *pedicels* 3–6 mm. long, filiform; *sepals* 3, oblong-lanceolate, obtuse, hooded, keeled, pale green with purplish margins, a prominent mid-rib and two more or less prominent lateral nerves, apically few-ciliate; *petals* 3, equal, rhombic, blue with a decided lavender tinge, 6–8 mm. long by 8–10 mm. wide; *stamens* 6, all perfect, the posterior stamen beset slightly above the middle of the filament with a thick collar of short yellow hairs, bluish below the hairs to the base, yellow or white and curved above to the yellow orbicular anther; the 2 postero-lateral stamens similar to the posterior one except slightly larger and the collars of hairs higher on the filament; the antero-lateral stamens with long slender filaments tapering at both ends and beset below the middle with a collar of fewer but longer hairs than those of the postero-lateral stamens, these hairs are bluish lavender in color, anthers oblong, blue; the anterior stamen similar to the antero-lateral ones except slightly larger, and with a stouter filament which tapers upward only and is entirely naked; all three anterior stamens usually larger throughout than the three posterior; *ovary* white, attenuate above into a curved white style terminated by a yellowish stigma; *ovules* laterally attached to the central placenta; seeds essentially similar to those of *C. anomala.*

Cleistogamous flowers occur on the lower portions of the stems both above and below the soil surface, appearing in general before the aerial ones, usually singly disposed at the ends of positively geotropic capillary branches, each of which bears from one to three much reduced leaves (usually only sheaths 5–6 mm. long) below the flower; *sepals* similar to above except less hooded, smaller and decidedly purplish throughout; *petals* also similar except progressively smaller downward on the stem, those below the soil surface much reduced; *stamens* slenderer, less hairy, and with anthers much reduced; *ovary* and stigma similar but with a shorter style; *ovules* two in each cavity, superimposed; *seeds* similar to those of *C. anomala* in that the endosperm is separated on one side by a suture which extends to the embryo-cavity; but the seeds from cleistogamous flowers are much rougher, with scalloped, shelving, lateral ridges, and are larger.

Characteristics which unmistakably ally *C. pringlei* to *C. anomala* are: Branches breaking through the leaf sheaths; the exactly similar stamens of four kinds; and the ovaries, ovules, and seeds. The possession of three equal petals and of cleistogamous habit is not shared by *C. anomala;* but the presence and absence of both these characteristics are to be found within the genus *Commelina*, and are certainly not sufficient ground upon which to base a generic distinction.

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Explanation of plates

PLATE 26

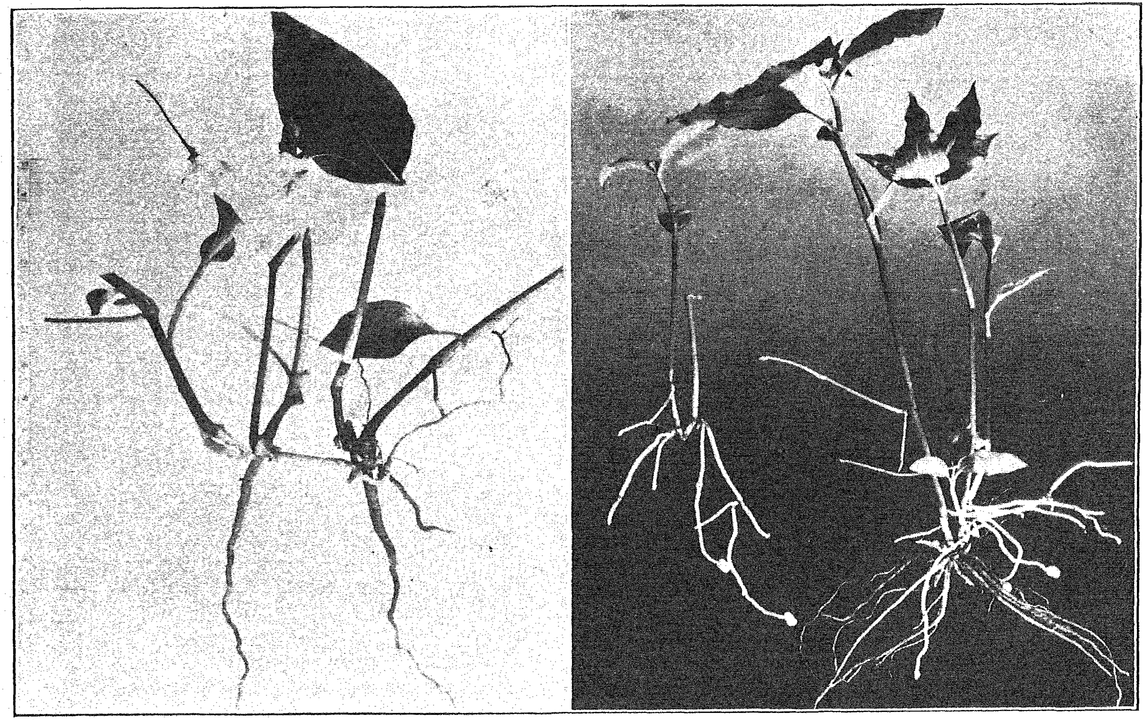
FIG. 1. Flowers and stolon. Most of the roots have been cut away in order better to show the stolon. × 1/2.

FIG. 2. General growth habit and cleistogamy. × 1/5.

PLATE 27

FIG. 1. Detail of inflorescence. At right, an aerial flower and developing capsule; at left, an extreme of cleistogamy, developed underground; between intermediate stages just above ground surface. × 3/2.

FIG. 2. Normal aerial vegetative branches and inflorescence habit. × 1/4.



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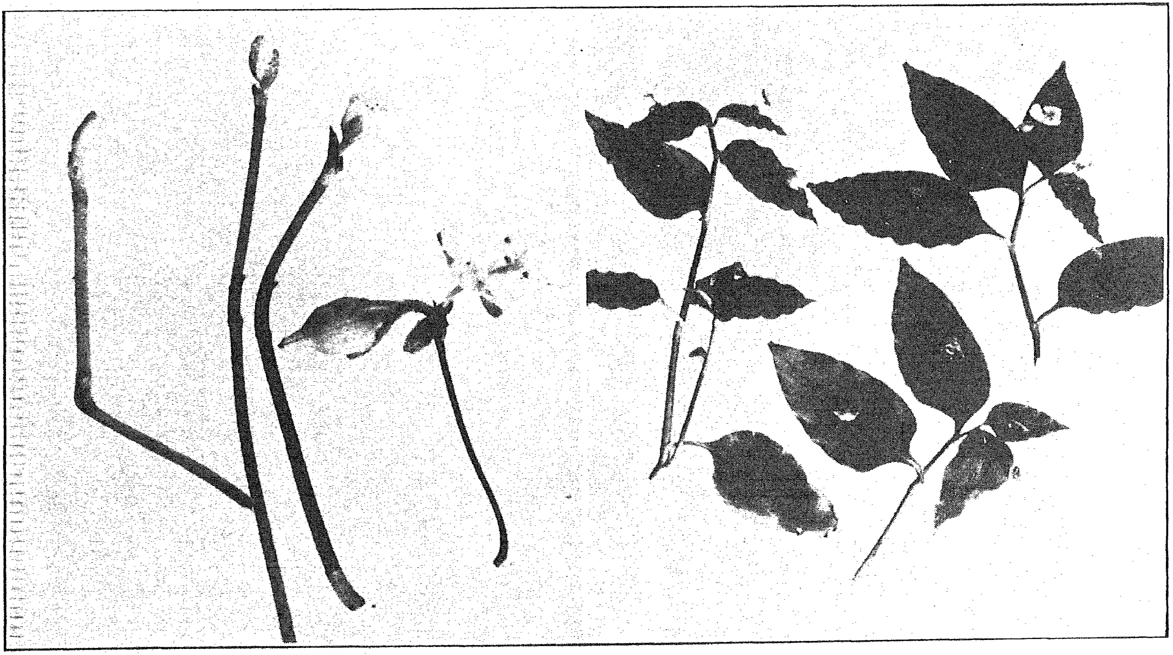
COMMELINANTIA PRINGLEI



COMMELINANTIA PRINGLEI

An analysis of the orthic tetrakaidecahedron

EDWIN B. MATZKE

(WITH SIX TEXT FIGURES)

In a series of painstaking and masterly researches Lewis (1923, 1925) has shown that cells of the elder pith, of human adipose tissue, and of the epithelium of the human oral cavity have on an average fourteen faces, and therefore are or tend to be tetrakaidecahedra. Some cells show a striking alternation of hexagonal and quadrilateral faces, suggesting the "plane-faced isotropic" or "orthic" tetrakaidecahedron that Kelvin (1887, 1894a, 1894b, 1904) described. Kelvin stated that space can be filled with equal and similar orthic tetrakaidecahedra, and that, further, they do not possess the unstable tetrahedral angles of the rhombic dodecahedron. And Lewis (1925, 1926) gives data to show that the orthic tetrakaidecahedron has less surface per unit of volume than the rhombic dodecahedron. Unit volumes of this configuration approach then as nearly to the condition of maximum volume with minimum surface as this can be achieved by aggregates of equal and similar units without spaces between. Lewis thinks that this is the pattern or type that cells in masses tend to simulate.

Lewis is not the first to have conceived of the possibility of cells' being tetrakaidecahedral. Thompson (1917) suggests this possibility, though he states that in parenchymatous tissue the dodecahedron is probably the form generally attained. According to Thompson, von Fedorow, in connection with his studies of crystals, described the tetrakaidecahedron before Kelvin, calling it the cubo-octahedron or hepta-parallelahedron; and von Fedorow also assumed that space could be completely filled with such figures. This latter point is also accepted by Tutton (1911).

Recently, however, the writings of both Thompson and Lewis have been criticized by Millis (1918, 1926). In his first article, prompted by Thompson's book, he says of the orthic tetrakaidecahedron: "Space can not be divided into equal volumes of this shape without surplus, or in other words these volumes can not be stacked together without leaving voids.

This may readily be determined by a study of the diedral angles, or practically by constructing a number of the tetrakaidecahedrons and trying it." In a later paper, after Lewis's publications, Millis says again: "The volume described, called the tetrakaidecahedron, does not possess the properties as stated. Equal volumes of this pattern will not fit together without voids, as a brief consideration of the diedral angles, or angles between faces, and the relations of these faces or a practical trial with the models would at once have shown."

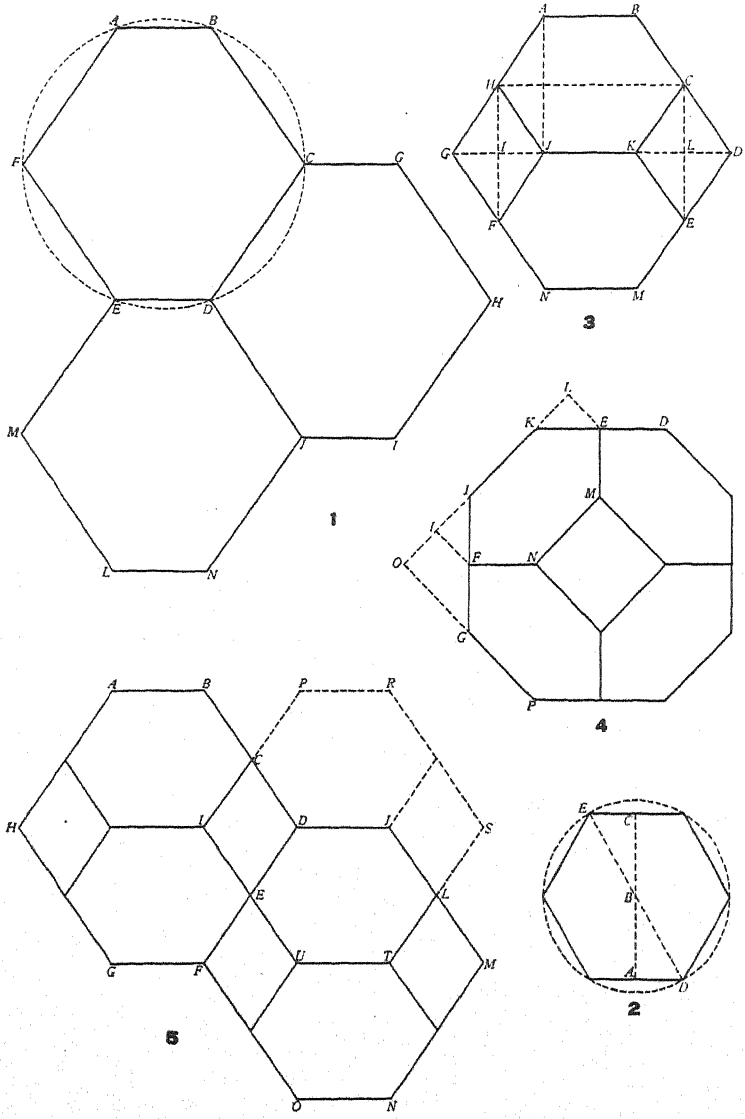
The orthic tetrakaidecahedron has fourteen faces, eight hexagonal and six square, all the sides of all the hexagons and all the squares being equal. Three of the sides of each hexagon also form the side of an adjacent square; the other three sides of each hexagon, which alternate with the first three, each form the side of an adjacent hexagon. It is evident then that there are dihedral angles formed by two adjacent hexagons, and by an adjacent square and hexagon; and an examination of the polyhedron reveals that these two angles are different. If now the dihedral angles are counted, it will be seen that there are twelve dihedral angles formed by adjacent hexagons, and twenty-four by adjacent squares and hexagons. Thus there are twice as many dihedral angles formed by adjacent squares and hexagons as by adjacent hexagons.

A section through the tetrakaidecahedron perpendicular to any edge shows a figure hexagonal in outline, with four longer and two shorter sides, *ABCDEF*, figure 1. The four longer sides, *BC*, *CD*, *EF*, and *FA*, are formed by lines perpendicular to two opposite and parallel edges of any of the hexagonal faces. This is shown by the line *AC* in figure 2. The shorter sides of the hexagon formed by the cross section, *AB*, *DE*, figure 1, are the same as the edge of a square face, or any line in the square face perpendicular to any edge. Furthermore, the opposite sides, *AB* and *DE*, *BC* and *EF*, *CD* and *FA*, are parallel as well as equal; hence von Fedorow's term hepta-parallelahedron. In addition, any line perpendicular to *ED* at *E* passes through *A;* a line perpendicular to *ED* at *D* passes through *B;* a line perpendicular to *EF* at *E* passes through *C*, etc. Therefore angles *FAB*, *ABC*, *CDE*, and *DEF* are all equal; and likewise angles *BCD* and *EFA* are equal.

The equality of these angles can also be demonstrated by circumscribing the hexagon, as shown in figure 1. It is also possible to circumscribe the lower right figure in Millis's first paper. While that figure is not simply a cross section perpendicular to an edge, it has the same outline as such a section. Each of the six angles of the inscribed hexagon thus becomes an inscribed angle, and hence is measured by one half its intercepted arc. It is evident that the arcs intercepted by angles *FAB*, *ABC*, *CDE*, and *DEF* are all equal; and likewise angles *BCD* and *EFA* intercept equal arcs.

The sum of the interior angles of any hexagon is equal to 720°. Therefore the sum of angles *ABC*, *BCD*, and *CDE* is equal to 360°, or equal to the sum of all the angles in one plane about any point. But angle *JDE* is equal to angle *ABC*, and angle *CDJ* is equal to angle *BCD*. Hence the sum of angles *CDE*, *JDE*, and *CDJ* is equal to 360°; in other words, there is no space left over when these angles are fitted together in the fashion indicated. It is obvious then that the sections of these polyhedra will fit together. Moreover the dihedral angles of the orthic tetrakaidecahedron are the same as the angles of the section perpendicular to any edge. Therefore, as far as the dihedral angles are concerned, the tetrakaidecahedra will stack without interstices.

The same subject can be approached from a different point of view. In figure 3, if *AB* is equal to x, *GA* (not *GHA*) is equal to $x\sqrt{3}$. This is evident from figure 2, in which *AC* is equal to *GA* in figure 3. If line *JK* in figure 3 is prolonged, it will meet a plane perpendicular to itself and passing through points *C* and *E* at *L*. If *JK* is prolonged in the other direction, it will meet a plane perpendicular to itself and passing through points *H* and *F* at *I*. Line *IL* then is equal to *HC*, and both are equal to *DE* in figure 2, or equal to $2x$. But *JK* is equal to x; therefore *IJ* and *KL* are each equal to $x/2$. If now *KJ* is prolonged through *I* till it meets the prolongation of the edge perpendicular to the plane of the paper at *G*, the distance from *I* to the point at which the prolongation of *KJ* meets the prolongation of the edge at *G* will also be $x/2$. This is shown more clearly in figure 4, in which the lettering is the same as in figure 3. There it is obvious that *JI* is equal to *IO*, which meets at *O* the prolongation of edge *PG* (the edge perpendicular to the plane of the paper at *G* in figure 3). *JO* in figure 4 is therefore equal to $2x/2$ or x. If now a



FIGS. 1–5. Relation of orthic tetrakaidecahedra and of their faces and angles.

plane section is cut through points A, G, N, in figure 3, it will also pass through points M, D, and B in figure 3, and through points G, N, M, and D in figure 4. Point J can be projected on this plane surface; and if this point is called J', GAJ' in figure 3 becomes a right triangle, of which one side is GA, equal to $x\sqrt{3}$, and another GJ', equal to x.

The cosine of angle AGJ' is equal to $x/x\sqrt{3}$, or $\sqrt{3}/3$, or .57735, and that angle, AGJ', is $54° 44' 8''$. The dihedral angle AGN in the tetrakaidecahedron is twice angle AGJ', or $109° 28' 16''$.

The sine of angle GAJ' is equal to $x/x\sqrt{3}$, or $\sqrt{3}/3$, or .57735, and the angle GAJ' is $35° 15' 52''$. The dihedral angle GAB in the tetrakaidecahedron is obviously $35° 15' 52''$ plus 90°, or $125° 15' 52''$. When the tetrakaidecahedra are fitted together as suggested by the sections in figure 1, two of the dihedral angles GAB and one dihedral angle AGN meet to fill up space about any of the edges of the figure, and they total 360°, leaving no space unoccupied. From a consideration of the dihedral angles, then, we are prompted to conclude that these polyhedra can be stacked without leaving voids.

Two tetrakaidecahedra may be placed together so that two hexagonal faces coincide, and that three edges of one of these hexagons which also form edges of squares coincide with three edges of the other hexagon which also form edges of adjacent hexagons. This arrangement is shown by the polyhedra $ABDFGH$ and $DJMNOF$ in figure 5. In the solid figure a line in the plane of face FED, perpendicular to ED at E, forms, with edge EI, the dihedral angle between a square and a hexagonal face. If we call such a dihedral angle α, and the dihedral angle between two hexagonal faces β, it has been shown above that $2\alpha + \beta = 360°$. Edge EI, then, forms an angle α with face FED at E, and forms an angle of 90° with edge ED at E. This fixes the position of edge EI in space.

If now a third tetrakaidecahedron is placed upon $DJMNOF$, as indicated by the dotted lines in figure 5, so that a hexagonal face of the third polyhedron coincides with face $DJLTUE$, and the edge at DE also forms the edge of a square face, then another edge of the square face, which we may call EI', is perpendicular to ED at E. It is also true that EI' forms an angle α at E with a line in face $DJLTUE$ perpendicular to ED at E.

And the dihedral angle at E in the polyhedron $DJMNOF$, formed by the two hexagonal faces whose common edge is ED is β. Adding these two angles we find that EI' makes an angle of $360° - (\alpha + \beta)$, or makes an angle α with face FED at E. Therefore EI' is fixed in space in the same position as EI, and hence they coincide. Thus it is evident that the tetrakaidecahedra will fit together without voids.

This is also indicated by the photograph in figure 6, in which fourteen of these polyhedra, modelled in wax, surround a central tetrakaidecahedron.

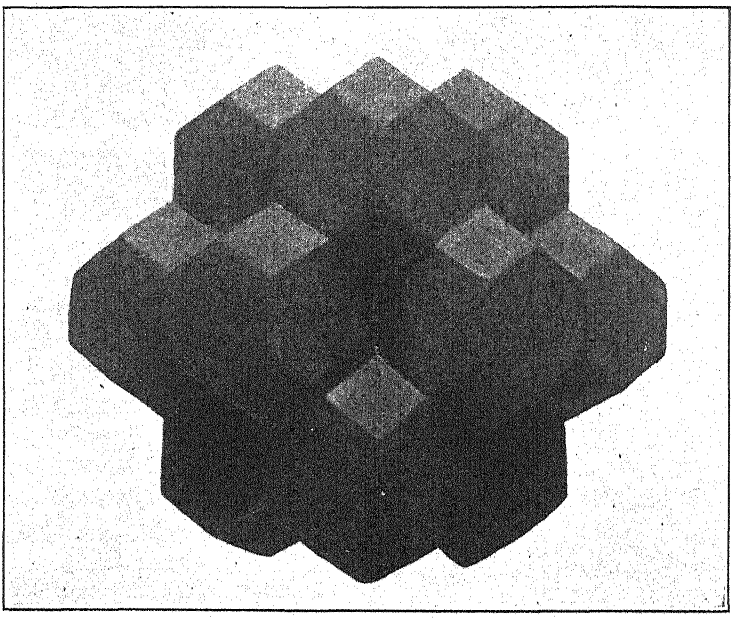


FIG. 6. Fourteen orthic tetrakaidecahedra surrounding a central one.

Millis says further: "Lord Kelvin's subsequent discussion of similar volumes with warped or distorted faces, which is referred to in Mr. Lewis's original papers, indicates that the error was later recognized by its distinguished author, though the subsequent treatment was far from convincing." Three of Kelvin's publications are cited in Lewis's papers, those of 1887, 1894b, and 1904. In the first of these, Kelvin discusses, in addition to the orthic tetrakaidecahedron, in which all the faces are plane surfaces, another tetrakaidecahedron having six quadrilateral plane faces. The eight hexagonal faces each have their six corners and three long diagonals in one plane, but the area between the diagonals curved. In this way a figure is obtained which has the angles between all the adjacent faces 120°, and hence is more stable than the orthic tetrakaidecahedron with its two kinds of dihedral angles. "The theoretical conclusion as to the angles for stable equilibrium (or pure minimum of the mathematical problem) therefore becomes, simply, that every angle of meeting of film surfaces is exactly 120°." Thus in his first discussion of the subject Kelvin described a tetrakaidecahedron with curved surfaces, not because the orthic figure would not stack without voids, but because the angles between the faces were not 120°. And his researches and those of Plateau (1873) led him to conclude that three films meeting in an edge would assume that angle.

The "Robert Boyle Lecture" (delivered in 1893, printed in 1894 and 1897) and the reprint of it in the appendix to the "Baltimore Lectures" (1904)—the only other publications of Kelvin cited by Lewis—contain no statement by the well known mathematician and physicist that orthic tetrakaidecahedra will not fit together without leaving unfilled spaces. The "warped and distorted faces" referred to by Millis, are apparently the curved hexagonal faces which Kelvin described in his first paper. If there is any statement in the very voluminous writings of Kelvin to the effect that orthic tetrakaidecahedra are unstackable, it has not found its way into the literature of the subject. In 1904 the "Baltimore Lectures," which were delivered in 1884, were published, with the "Robert Boyle Lecture" in the appendix. Three notes to the latter dated 1896, are added, but none on the disputed point. Several of the Baltimore discussions were written afresh in 1901, 1902, and 1903 for that edition, suggesting, at least, that from 1887 until 1896, and probably until 1904, Kelvin did not change his opinions on the subject; and there seems to be no reason for such a change.

The tetrakaidecahedron was useful to von Fedorow in the development of his theory of crystal structure; and the space-lattice concept developed for crystals might also serve, in a slightly different sense, for tissue systems, conceiving of homologous points in the cells or their walls as forming the points of the lattice. Different tissues, then, would in many cases at least have different symmetry patterns, and intermingling tissues would disclose interpenetrating space lattices.

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Literature cited

Kelvin, Lord. 1887. On the division of space with minimum partitional area. Phil. Mag. 5s. **24:** 503–514.

————. 1894a. On the homogeneous division of space. Roy. Soc. Proc. **55:** 1–16.

————. 1894b. The molecular tactics of a crystal. The Second Robert Boyle Lecture. Jour. Oxford Univ. Junior Scientific Club, no. 18, May 25, 1894. Oxford. (Also published in "The Robert Boyle Lectures," vol. I, Oxford, 1897.)

————. 1904. Baltimore lectures on molecular dynamics and the wave theory of light. Appendix H. London.

Lewis, F. T. 1923. The typical shape of polyhedral cells in vegetable parenchyma and the restoration of that shape following cell division. Proc. Amer. Acad. Arts and Sci. **58:** 537–552.

————. 1925. A further study of the polyhedral shapes of cells. I. The stellate cells of *Juncus effusus.* II. Cells of human adipose tissue. III. Stratified cells of human oral epithelium. Proc. Amer. Acad. Arts and Sci. **61:** 1–34.

————. 1926. An objective demonstration of the shape of cells in masses. Science **63:** 607–609.

Millis, J. 1918. A geometric basis for physical and organic phenomena. Science **48:** 353–360.

————. 1926. The shape of cells in masses. Science **64:** 225–226.

Plateau, J. 1873. Statique expérimentale et théorique des liquides soumis aux seules forces moléculaires. Paris.

Thompson, D'A. W. 1917. On growth and form. Cambridge.

Tutton, A. E. H. 1911. Crystallography and practical crystal measurement. London.

INDEX TO AMERICAN BOTANICAL LITERATURE
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Abbott, E. V. Taxonomic studies on soil fungi. Iowa State Coll. Jour. Sci. **1**: 15–36. *f. 1–4.* 1 O 1926.

Abbott, O. D. The utilization of pentoses by yeasts, and the composition of plant gums. Missouri Agr. Exp. Sta. Res. Bull. 85: 1–29. *f. 1.* Mr 1926.

Alberts, H. W. A method for calculating linkage values. Genetics **11**: 235–248. *f. 1, 2.* "My" 19 O 1926.

Alexander, E. J. *Azalea viscosa glauca.* Addisonia **11**: 35–36. *pl. 370.* "S" 9 D 1926.
Native of eastern North America.

Alexander, E. J. *Eryngium aquaticum.* Addisonia **11**: 43–44. *pl. 374.* "S" 9 D 1926.
Native of southeastern North America.

Alexander, E. J. *Erythronium americanum.* Addisonia **11**: 17–18. *pl. 361.* "Je" 13 O 1926.
Native of eastern North America.

Alexander, E. J. *Ilex decidua.* Addisonia **11**: 47–48. *pl. 376.* "S" 9 D 1926.
Native of southeastern North America.

Allee, W. C. Measurement of environmental factors in the tropical rain-forest of Panama. Ecology **7**: 273–302. *f. 1–9.* "Jl" 4 Au 1926.

Anderssen, F. G. A device for maintaining constant level of culture solutions. Plant Physiol. **1**: 417–418. *f. 1.* O 1926.

Andrews, F. M. Etiolation. Proc. Indiana Acad. Sci. **35**: 180–181. "1925" 1926.

Andrews, F. M. Food storage. Plant Physiol. **1:** 287–288. Jl 1926.

Andrews, F. M. Misdirected leaves of *Setaria glauca.* Proc. Indiana Acad. Sci. **35:** 181. "1925" 1926.

Andrews, F. M. Starch formation. Proc. Indiana Acad. Sci. **35:** 182–184. "1925" 1926.

Andrews, F. M. An unusual *Impatiens biflora* II. Proc. Indiana Acad. Sci. **35:** 179. "1925" 1926.

Appleman, C. O., and Miller, E. V. A chemical and physiological study of maturity in potatoes. Jour. Agr. Res. **33:** 569–577. 15 S 1926.

Arbuckle, H. B. and Thies, O. J., Jr. Variation of protein content of corn. V. Jour. Elisha Mitchell Sci. Soc. **42:** 113–117. O 1926.

Armitage, E. Notes on Canary Island bryophytes. Bryologist **29:** 40–53. "S" 12 O 1926.

Arnell, H. W. Per Dusén: a biographical sketch. Bryologist **29:** 57–59. *port.* "S" 12 O 1926.

Aslander, A. Chlorates as plant poisons (a preliminary report). Jour. Am. Soc. Agron. **18:** 1101–1102. D 1926.

Asplund, E. Contributions to the flora of the Bolivian Andes. Arkiv Bot. **20A**^{7}**:** 1–38. *f. 1–7.* 28 My 1926.

Atanasoff, D. Sprain on internal brown spot of potatoes. Phytopathology **16:** 711–722. *f. 1–3 + pl. 36.* 15 O 1926.

Baird, E. A. The structure and behavior of the nucleus in the life history of *Phycomyces nitens* (Agardh) Kunze and *Rhizopus nigricans* Ehrbg. Trans. Wisconsin Acad. Sci. Arts & Lett. **21:** 357–380. *pl. 14, 15.* 1924.

Baker, W. B. Studies in the life history of "*Euglena.*" I. *Euglena agilis* Carter. Biol. Bull. **51:** 321–361. *pl. 1, 2.* N 1926.

Ball, C. R. Canadian willows of sections *Pentandrae, Nigrae* and *Albae.* Canad. Field Nat. **40:** 145–152. O 1926.

Barnhart, J. H. The Botanical Congress at Ithaca. Jour. N. Y. Bot. Gard. **27:** 207–209. S 1926.

Barnhart, J. H. Brief sketches of some collectors of specimens in the Barton Herbarium. Bartonia 9: 35–42. O 1926.

John Adlum, Zaccheus Collins, Alire Raffeneau-Delile, C. F. Denke, Andrew Ellicott, Aloysius Enslen, Thos. Horsefield, Matthias Kinn, John Lyon, Bernard McMahon, Michaux, Pursh, Rafinesque, Winthrop Sargent, David Thomas and P. J. F. Turpin.

Bartram, E. B. *Tortula fragilis* Tayl. and *Tortula bogotensis* (H.P.E.) Mitt. Bryologist **29:** 53–54. "S" 12 O 1926.

Bates, C. G. Some relations of plant ecology to silvicultural practice. Ecology **7:** 469–480. 5 O 1926.

Bell, A. M. Some anomalies in the development of the seed of *Pinus*. Proc. Indiana Acad. Sci. **35:** 189–196. *f. 1–5.* "1925" 1926.

Belyea, H. C., and MacAloney, H. J. Weather injury to terminal buds of Scotch pine and other conifers. Jour. For. **24:** 685–690. O 1926.

Bennett, H. H. The forests of Cuba's everglades. Nat. Mag. **9:** 23–26. *Illust.* Ja 1927.

Berger, A. Cantuas. Gard. Chron. **III, 80:** 269. *f. 125.* 2 O 1926.

Berger, A. Carlos Wercklé. Zeit. Sukkulent. **2:** 200–202. Je 1926.

Born 1860. Died 24 N 1924.

Berger, A. Die Entwicklungen der Kakteen. i–iv, 1–105. *illust.* Jena, Fischer, 1926.

Berkeley, G. H., and Jackson, A. B. Studies in raspberry diseases. Mosaic, leaf curl, rosette, and wilt of the raspberry. Canada Dept. Agr. Pamphlet n.s. 72: 1–15. *f. 1–6.* 1926.

Berry, E. W. The romance of collecting fossil plants. Nat. Hist. **26:** 475–485. *f. 1–6.* S–O 1926.

Blake, S. F. Five new American Melampodiinae. Jour. Washington Acad. Sci. **16:** 418–422. 19 S 1926.

In *Clibadium*, *Ichthyothere*, *Polymnia*, and *Melampodium*.

Blake, S. F. The identity of '*Cuspa*' (*Conoria? Cuspa* H.B.K.) Bull. Torrey Club **53**: 601–604. "N" 29 D 1926.

Bowen, R. H. Chondriosomes and golgi apparatus in plant cells. Science II, **64**: 188–190. 20 Au 1926.

Boynton, K. R. *Cercidiphyllum japonicum.* Addisonia **11**: 23–24. *pl. 364.* "Je" 13 O 1926.
Native of China and Japan.

Boynton, K. R. *Lespedeza Sieboldii.* Addisonia **11**: 21. *pl. 363.* "Je" 13 O 1926.
Native of Japan.

Boynton, K. R. *Nymphoides Humboldtianum.* Addisonia **11**: 25–26. *pl. 365.* "Je" 13 O 1926.
Native of tropical America.

Boynton, K. R. *Pinus peuce.* Addisonia **11**: 45–46. *pl. 375.* "S" 9 D 1926.
Native of southeastern Europe.

Boynton, K. R. *Turraea floribunda.* Addisonia **11**: 39. *pl. 372.* "S" 9 D 1926.
Native of tropical Africa.

Boynton, K. R., and Poole, E. W. *Primula kewensis.* Addisonia **11**: 29–30. *pl. 367.* "Je" 13 O 1926.
Of garden origin.

Brewer, P. H., Kendrick, J. B., and Gardner, M. W. Effect of mosaic on carbohydrate and nitrogen content of the tomato plant. Phytopathology **16**: 843–851. 15 N 1926.

Briggs, F. N. Seed treatments for the control of bunt of wheat. Phytopathology **16**: 829–842. 15 N 1926.

Britton, N. L. Studies of West Indian plants. XIII. 74. Undescribed species from Cuba. 75. Undescribed species from Trinidad. 76. An undescribed tree from Porto Rico. Bull. Torrey Club **53**: 457–471. 30 O 1926.

Britton, N. L. The swamp cypresses. Jour. N. Y. Bot. Gard. **27**: 205–207. S 1926.

Britton, N. L. *Teedia lucida.* Addisonia **11**: 37. *pl. 371.* "S" 9 D 1926.
Native of southern Africa.

Brooks, A. N. Studies of the epidemiology and control of fire-blight of apple. Phytopathology **16:** 665–696. *f. 1.* 15 O 1926.

Brooks, M. *Asplenium Gravesii* in West Virginia. Am. Fern. Jour. **16:** 97–98. 28 S 1926.

Brownell, L. W. Poison sumac—beware. Nat. Mag. **8:** 237–238. *illust.* O 1926.

Burkholder, W. H., and Muller, A. S. Hereditary abnormalities resembling certain infectious diseases in beans. Phytopathology **16:** 731–737. *f. 1, 2.* 15 O 1926.

Burrell, R. O. Effect of certain deficiencies on nitrogen metabolism of plants. Bot. Gaz. **82:** 320–328. 24 N 1926.

Burt, E. A. The Thelephoraceae of North America XV. (Conclusion, with supplement and general index.) Ann. Missouri Bot. Gard. **13:** 173–354. 20 S 1926.
Many species described as new.

Bush, B. F. Notes on trees and shrubs of Missouri. Am. Midl. Nat. **10:** 133–158. N 1926.

Campbell, D. H. An outline of plant geography. i–ix, 1–392. *f. 1–101 + pl. 1–52.* New York, Macmillan, 1926.

Carsner, E. Resistance in sugar beets to curly-top. U. S. Dept. Agr. Circ. 388: 1–8. *f. 1–4.* Jl 1926.

Chen, K. K. A study of *Illicium religiosum* (mang tsao). Jour. Am. Pharm. Assoc. **15:** 861–866. O 1926.

Cheney, R. H. The ancient and modern use of plant arrow poisons. Sci. Mo. **23:** 552–555. D 1926.

Chodat, R., and Rehfous, L. La végétation du Paraguay. XIII. (Nyctaginacées.) Bull. Soc. Bot. Geneva II, **17:** 127–164. *f. 1–51 + pl. 1.* 10 Ap 1926.

Christensen, C. Revised list of Hawaiian Pteridophyta. Bull. Bernice P. Bishop Mus. 25: 1–30. 1925.

Chrysler, M. A. Vascular tissues of *Microcycas calocoma.* Bot. Gaz. **82:** 233–252. *f. 1–3 + pl. 16–18.* 24 N 1926.

Clark, N. A. Plant growth-promoting substances, hydrogen-ion concentration and the reproduction of *Lemna*. Plant Physiol. **1**: 273–279. *f. 1.* Jl 1926.

Clausen, R. E., and Goodspeed, T. H. Inheritance in *Nicotiana tabacum*. VII. The monosomic character, "fluted." Univ. California Publ. Bot. **11**: 61–82. *f. 1*, 2 + *pl. 1–3.* 14 O 1926.

Clausen, R. E., and Goodspeed, T. H. Interspecific hybridization in *Nicotiana*. III. The monosomic *tabacum* derivative "corrugated," from the *sylvestris-tabacum* hybrid. Univ. California Publ. Bot. **11**: 83–101. *f. 1–4.* 14 O 1926.

Cleland, R. E. Cytological study of meiosis in anthers of *Oenothera muricata*. Bot. Gaz. **82**: 55–70. *pl. 3, 4.* 30 S 1926.

Clute, W. N. The blazing stars. Am. Bot. **32**: 139–140. *illust.* O 1926.
Liatris species.

Cockerell, T. D. A. An alga from the Eocene of Colorado. Torreya **26**: 111–112. *f. 1.* 28 D 1926.
Genus *Phenacocladus* described as new.

Cockerell, T. D. A. The antiquity of the Labiatae or mint family. Nature **118**: 696. 13 N 1926.

Coker, W. C., and Braxton, H. H. New water molds from the soil. Jour. Elisha Mitchell Sci. Soc. **42**: 139–149. *pl. 10–15.* O 1926.

Coles, H. W. The digestion of pectin and methylated glucoses by various organisms. Plant physiol. **1**: 379–385. O 1926.

Conrad, C. M. A biochemical study of the insoluble pectic substances in vegetables. Am. Jour. Bot. **13**: 531–547. *f. 1–3.* 16 N 1926.

Cook, O. F., and Hubbard, J. W. New species of cotton from Colombia and Ecuador. Jour. Washington Acad. Sci. **16**: 545–552. 3 D 1926.

Cooper, W. S. The fundamentals of vegetational change. Ecology **7**: 391–413. 5 O 1926.

Copeland, E. B. Filices aliquot novae orientales. Philipp. Jour. Sci. **30:** 325–333. *pl. 1.* Jl 1926.
Genus *Tectaridium* and several species described as new.

Couch, J. N. Heterothallism in *Dictyuchus*, a genus of the water moulds. Ann. Bot. **40:** 849–881. *f. 1–3* + *pl. 35–38.* O 1926.

Cowgill, H. B. Some panicle characters of sorgo. U. S. Dept. Agr. Bull. 1386: 1–37. *f. 1, 2* + *pl. 1–16.* Jl 1926.

Crozier, W. J. On curves of growth, especially in relation to temperature. Jour. Gen. Physiol. **10:** 53–73. *f. 1–8.* 20 S 1926.

Cuno, J. B. Utilization of dogwood and persimmon. U. S. Dept. Agr. Bull. 1436: 1–43. *f. 1–24.* S 1926.

Darrow, G. M. Abnormal growth of raspberry. Jour. Hered. **17:** 250. *f. 6.* "Jl" 8 S 1926.

Darrow, G. M. Raspberry breeding experiments. Hybrids and back crosses between red and black varieties. Jour. Hered. **17:** 339–348. *f. 9–14.* "S" 28 O 1926.

Davidson, A. *Gilia inconspicua* var. *dentiflora* n. var., *Tissa-leucantha* var. *glabra* n. var. Bull. So. California Acad. Sci. 25: 84. S–D 1926.

Davis, B. M. The history of *Oenothera biennis* Linnaeus, *Oenothera grandiflora* Solander, and *Oenothera Lamarckiana* of DeVries in England. Proc. Am. Phil. Soc. **65:** 349–378 *pl. 1–4.* 22 Ap 1926.

Davis, J. J. Notes on parasitic fungi in Wisconsin. IX, X, XI, XII, XIII, XIV. Trans. Wisconsin Acad. Sci., Arts & Lett. **21:** 251–302. *f. 1–4.* 1924; **22:** 155–192. *f. 1.* 1926.
For corrections by author to part XIII see Mycologia 19: 38. 1 Ja 1927.

Davy, J. B. Notes on tropical African trees. Yale Univ. School For. Trop. Woods 8: 17–18. 1 D 1926.

Deam, C. C. Plants new or rare in Indiana.—XIII. Proc. Indiana Acad. Sci. **35:** 197–198. "1925" 1926.

Delwiche, E. J., and Renard, E. J. Breeding new varieties of canning peas. Wisconsin Agr. Exp. Sta. Res. Bull. 70: 1–31. *f. 1–15.* O 1926.

Demerec, M. Heritable characters of maize. XXV. Piebald seedlings. Jour. Hered. **17**: 301–306. *f. 11–13.* "Au" 9 O 1926.

Deuber, C. G. Influence of mineral elements upon development of chloroplast pigments of soy beans. Bot. Gaz. **82**: 132–153. *f. 1–5.* 28 O 1926.

Dobbie, H. B. Gathering ferns in New Zealand. Am. Fern Jour. **16**: 71–77. 28 S 1926.

Dodge, B. O., and Wilcox, R. B. Diseases of raspberries and blackberries. U. S. Dept. Agr. Farmers Bull. 1488: 1–32. *f. 1–20.* Je 1926.

Drain, B. D. Temperature and respiratory enzymes of apples. Bot. Gaz. **82**: 183–194. *pl. 11.* 28 O 1926.

Ellen, Sister M. Some ferns of southwestern Wisconsin. Wisconsin Acad. Sci., Arts & Lett. **21**: 249–250. 1924.

Erdman, L. W. Studies on inoculated soybeans: I. The importance of determining the number and size of soybean nodules for evaluating relative efficiencies of 2 or more cultures. Jour. Am. Soc. Agron. **18**: 798–804. S 1926.

Evans, A. W. The Hepaticae of Fisher's Island. Torreya **26**: 85–86. 30 O 1926.

Evans, P. A. An ecological study in Utah. Bot. Gaz. **82**: 253–285. *f. 1–14.* 24 N 1926.
Salt Lake County.

Eyster, W. H. The effect of environment on variegation patterns in maize pericarp. Genetics **11**: 372–386. *f. 1–4.* "Jl" 24 D 1926.

Faris, J. A. Cold chlorosis of sugar cane. Phytopathology **16**: 885–891. *f. 1–3.* 15 N 1926.

Fitzpatrick, H. M. Mushrooms on trees. Tree Talk **8**[1]: 4–6. *illust.* 1926.

Folsom, D., Schultz, E. S., and Bonde, R. Potato degeneration diseases: Natural spread and effect upon yield. Maine Agr. Exp. Sta. Bull. 331: 1–112. Mr 1926.

Freeman, O. M. *Parthenium auriculatum* in Burke County, North Carolina. Rhodora **28:** 208. "O" 6 N 1926.

Frey, C. N. The cytology and physiology of *Venturia inequalis* (Cooke) Winter. Trans. Wisconsin Acad. Sci., Arts & Lett. **21:** 303–343. *pl. 10–11.* 1924.

Friesner, G. M. Bacteria in the roots of *Gleditsia triacanthos* L. Proc. Indiana Acad. Sci. **35:** 215–224. *f. 1–6.* "1925" 1926.

Fritz, E. How a tree robbed a bird. Nat. Mag. **8:** 349. *illust.* D 1926.

A woodpecker hole in a redwood healed over by the tree.

Fuller, A. M. Our Wisconsin orchids and their protection. Yearbook Public Mus. Milwaukee **4:** 186–192. *illust.* O 1926.

Gager, C. S. General botany; with special reference to its economic aspects. i–xvi, 1–1056. *f. 1–689.* Phila., Blakiston, 1926.

3 chapters on heredity and variation in plants by O. E. White.

Gaines, E. F. and Carstens, A. The linkage of pubescent node and beard factors as evidenced by a cross between two varieties of wheat. Jour. Agr. Res. **33:** 753–755. 15 O 1926.

Gardner, M. W. Indiana plant diseases, 1924. Proc. Indiana Acad. Sci. **35:** 237–257. *f. 1–8.* "1925" 1926.

Gardner, N. L. New Rhodophyceae from the Pacific coast of North America. I. Univ. California Publ. Bot. **13:** 205–226. *pl. 15–21.* 6 N 1926.

Many species and combinations described as new.

Garrett, A. O. *Azolla caroliniana* Willd. in Utah. Am. Fern Jour. **16:** 98. 28 S 1926.

West of Provo, near Utah Lake.

Garrett, A. O. A new smut *Urocystis Flowersii* Garrett. Mycologia **18:** 286. 1 N 1926.

Gates, F. C. Plant successions about Douglas Lake, Cheboygan County, Michigan. Bot. Gaz. **82**: 170–182. *f. 1–3.* 28 O 1926.

Gerhardt, F. Some chemical changes incident to ripening and storage in the Grimes apple. Plant Physiol. **1**: 251–264. *f. 1–6.* Jl 1926.

Gilbert, B. E. The response of certain photoperiodic plants to differing temperature and humidity conditions. Ann. Bot. **40**: 315–320. *f. 1–2.* Ap 1926.

Gill, L. T. The hibiscus—Hawaii's flower. Nat. Mag. **8**: 289–291. *illust.* N 1926.

Ginsburg, J. M., and Shive, J. W. The influence of calcium and nitrogen on the protein content of the soybean plant. Soil Sci. **22**: 175–192. *pl. 1–3.* S 1926.

Giöbel, G. The relation of the soil nitrogen to nodule development and fixation of nitrogen by certain legumes. New Jersey Agr. Exp. Sta. Bull. 436: 1–125. *f. 1–22.* Je 1926.

Gleason, H. A. In British Guiana jungles. Jour. N. Y. Bot. Gard. **27**: 250–251. N 1926.
Abstract of a lecture.

Goldsmith, G. W., and Smith, J. H. C. Some physico-chemical properties of spruce sap and their seasonal and altitudinal variation. Colorado Coll. Publ., Gen. Ser. 137: 11–71. F 1926.

Goldstein, B. A cytological study of the leaves and growing points of healthy and mosaic diseased tobacco plants. Bull. Torrey Club **53**: 499–599. *f. 1–4 + pl. 18–29.* "N" 29 D 1926.

Goldsworthy, M. C. Attempts to cultivate the tobacco mosaic virus. Phytopathology **16**: 873–875. 15 N 1926.

Goldsworthy, M. C. Studies on the spot disease of cauliflower; a use of serum diagnosis. Phytopathology **16**: 877–884. 15 N 1926.

Goodspeed, T. H., Clausen, R. E., and Chipman, R. H. Interspecific hybridization in Nicotiana. IV. Some cytological features of the *paniculata-rustica* hybrid and its derivatives. Univ. California Publ. Bot. **11**: 103–115. *f. 1–6.* 9 N 1926.

Graves, A. H. The cause of the persistent development of basal shoots from blighted chestnut trees. Phytopathology **16**: 615–621. *f. 1.* 15 S 1926.

Grout, A. J. Spore dispersal in sphagnum. Bryologist **29**: 55. "S" 12 O 1926.

Guba, E. F. Injury to greenhouse plants from hydrocyanic acid gas, following the application of copper fungicides. Phytopathology **16**: 633–634. 15 S 1926.

Guimares, J. S. A phytotechnical study of a useful wild Brazilian plant. Int. Rev. Sci. & Prac. Agr. 4: 241–250. *f. 33 + col. pl. 6.* Ap–Je 1926.
The "Gravitaia" *Tuber brasiliensis.*

Gundersen, A. The need of an enlarged list of botanical nomina conservanda. Science II, **64**: 182–183. 20 Au 1926.

Gustafson, F. G. Growth studies on fruits. Plant Physiol. **1**: 265–272. *f. 1–4.* Jl 1926.

Hafner, V. E. Angleton grass. Texas Agr. Exp. Sta. Bull. 342: 1–11. Je 1926.

Hampton, H. C., and Gordon, I. M. A suggested course in plant physiology. Science II, **64**: 417–419. 29 O 1926.

Hansen, A. A. Recent Indiana weeds, 1925. Proc. Indiana Acad. Sci. **35**: 199–200. "1925" 1926.

Hansen, H. N. "Pink-root" of onions caused by *Phoma* sp. Science II. **64**: 525. 26 N 1926.

Hansen, H. N. A simple method of obtaining single-spore cultures. Science II, **64**: 384. 15 O 1926.

Hansford, C. G. Panama disease in Jamaica. Microbiol. Circ. Jamaica Dept. Sci. & Agr. 5: 1–35. 1926.

Hansford, C. G., Murray, P. W., and Storey, H. The mosaic disease of sugar cane and its control in Jamaica, with a note on streak disease of Uba cane. Microbiol. Circ. Jamaica Dept. Agr. 6: 1–39. 1926.

Hanson, H. C., and Brenke, B. Seasonal development of growth layers in *Fraxinus campestris* and *Acer saccharinum.* Bot. Gaz. **82**: 286–305. *f. 1, 2 + pl. 19–21.* 24 N 1926.

Harper, R. M. A middle Florida cedar swamp. Torreya **26**: 81–84. 30 O 1926.

Harris, G. H. An investigation of root activity of apple and filberts, especially during the winter months. Sci. Agr. **7**: 92–99. *f. 1–6.* N 1926.

Harshberger, J. W. America's first real garden. Garden & Home Build. **44**: 228–232. N 1926.
Prince's Linnaean Botanical Garden at Flushing, Long Island.

Harter, L. L. Bud sports in sweet potatoes. Jour. Agr. Res. **33**: 523–525. *f. 1 + col. pl. 1.* 15 S 1926.

Haupt, A. W. Morphology of *Preissia quadrata.* Bot. Gaz. **82**: 30–54. *f. 1–16 + pl. 1, 2.* 30 S 1926.

Hawkins, S. Some Xylarias of Indiana. Proc. Indiana Acad. Sci. **35**: 225–229. "1925" 1926.

Hayes, H. K. Breeding improved varieties of smooth-awned barleys. Jour. Hered. **17**: 371–381. *f. 9–14.* 27 N 1926.

Hayes, H. K., and Brewbaker, H. E. Factors for color inheritance of aleurone and endosperm in maize. Jour. Am. Soc. Agron. **18**: 761–767. S 1926.

Heald, F. D. Manual of plant diseases. i–xiii, i–891. *f. 1–272* N. Y., McGraw Hill, 1926.

Hein, I. The mildew *Sphaerotheca castagnei* on *Bidens* as a fungus for class use. Torreya **26**: 113–115. 28 D 1926.

Henry, A. W. Flax rust, a preventable disease. Minnesota Agr. Exp. Sta. Ext. Div. Spec. Bull. 109: 1–8. *f. 1–3.* My 1926.

[**Herrera, A. L.**] Catalogo alfabetico de nombres vulgares y cientificos de plantas que existen en Mexico. .fol. 11: 281–329; fol. 12: 330–396; fol. 13: 397–422; fol. 14: 423–438; fol. 15: 439–478. Mexico, [1926].

Hesler, L. R. The teaching of elementary plant pathology. Phytopathology **16:** 739–744. 15 O 1926.

Higgins, B. B. Bacterial spot of peach. Georgia Agr. Exp. Sta. Circ. 79: 1–8. *f. 1–4.* Au 1926.

Hill, A. W. The Royal Botanic Gardens at Kew, England. Jour. N. Y. Bot. Gard. **27:** 241–243. N 1926.

Hitchcock, A. S. An international committee on botanical nomenclature. Science II, **64:** 290–291. 24 S 1926.

Hoagland, D. R., Hibbard, P. L., and Davis, A. R. The influence of light, temperature, and other conditions on the ability of *Nitella* cells to concentrate halogens in the cell sap. Jour. Gen. Physiol. **10:** 121–146. *f. 1.* 20 S 1926.

Hoffmann, R. *Lygodium palmatum* and *Agrimonia mollis* in Berkshire County, Massachusetts. Rhodora **28:** 179–180. 20 S 1926.

Hollick, A. Fossil walnuts and lignite from Porto Rico. Jour. N. Y. Bot. Gard. **27:** 223–227. *f. 1.* O 1926.
Juglans archaecantillana described as new.

Holman, R. M., and Brubaker, F. On the longevity of pollen. Univ. California Publ. Bot. **13:** 179–204. 14 S 1926.

Howe, M. A. Reef-building and land-forming plants. Jour. N. Y. Bot. Gard. **27:** 232–234. O 1926.
Abstract of a lecture.

Howe, M. A. A visit from Dr. Arthur W. Hill. Jour. N. Y. Bot. Gard. **27:** 243–245. N 1926.

Howes, P. G. Micro gardens. Nat. Mag. **8:** 215–217. *illust.* O 1926.

Hynes, H. J. Studies on the reaction to stem rust in a cross between Federation wheat and Khapli emmer, with notes on the fertility of the hybrid types. Phytopathology **16:** 809–827. *pl. 48–51.* 15 N 1926.

Imms, A. D. The biological control of insect pests and injurious plants in the Hawaiian Islands. Ann. Applied Biol. **13:** 402–423. *pl. 12.* Au 1926.

Irwin, M. Exit of dye from living cells of *Nitella* at different pH values. Jour. Gen. Physiol. **10:** 75–102. *f. 1–4.* 20 S 1926.

Irwin, M. The penetration of basic dye into *Nitella* and *Valonia* in the presence of certain acids, buffer mixtures, and salts. Jour. Gen. Physiol. **10:** 271–288. 20 N 1926.

Jaeger, E. C. A preliminary report on the flora of the Charleston Mountains of Nevada. Occasional Papers Riverside Junior Coll. **1:** 1–15. *illust.* 1 Ap 1926.

Jeffrey, E. C., and Wetmore, R. H. On the occurrence of parichnos in conifers. Ann. Bot. **40:** 799–811. *f. 1–7 + pl. 33.* O 1926.

Jehle, R. A. Disastrous effect of mosaic on the McCormick potato. Maryland Agr. Exp. Sta. Bull. 282: 215–219. *f. 1, 2.* My 1926.

Johnson, F. W. Notes on the distribution of *Serapias helleborine* L. in western New York. Bartonia 9: 10. O 1926.

Johnson, G. On the irregular occurrence of certain native plants. Bartonia 9: 16. O 1926.

Johnson, H. M., Hanzlik, E. J., and Gibbons, W. H. Red alder of the Pacific northwest. U. S. Dept. Agr. Bull. 1437: 1–46. *f. 1–11.* S 1926.

Johnson, J. The attenuation of plant viruses and the inactivating influence of oxygen. Science II, **64:** 210. 27 Au 1926.

Johnson, J. Some points of view on the plant virus problem. Phytopathology **16:** 745–751. 15 O 1926.

Jones, F. R., and McCulloch, L. A bacterial wilt and root rot of alfalfa caused by *Aplanobacter insidiosum* L.McC. Jour. Agr. Res. **33:** 493–521. *pl. 1–6.* 15 S 1926.

Kater, J. McA. Chromosomal vesicles and the structure of the resting nucleus in *Phaseolus.* Biol. Bull. **51:** 209–221. S 1926.

Kearney, T. H. Correlations of seed, fiber, and boll characters in cotton. Jour. Agr. Res. **33**: 781–796. *f. 1, 2.* 15 O 1926.

K[earney], T. H. William Edwin Safford. Jour. Hered. **17**: 365–366. *port.* 27 N 1926.
Born 14 D 1859. Died 10 Ja 1926.

Kearney, T. H., and Peebles, R. H. Heritability of different rates of shedding in cotton. Jour. Agr. Res. **33**: 651–661. *f. 1.* 1 O 1926.

Kearney, T. H. and Porter, D. D. Bagging cotton flowers to prevent accidental cross-pollination. Jour. Hered. **17**: 273–279. *f. 1, 2.* "Au" 9 O 1926.

Keeble, F. Life of plants. i–xii, 1–256. *f. 1–51.* N. Y., Oxford Univ. Pr., Am. Branch, 1926.

Keefe, A. M. A preserving fluid for green plants. Science II, **64**: 331–332. 1 O 1926.

Kiernan, F. P., and White, O. E. Inheritance in four o'clocks. Jour. Hered. **17**: 383–386. 27 N 1926.

Kirkwood, J. E. Botany of the Montana Rockies. Torreya **26**: 105–109. 28 D 1926.

Knowlton, D. Are some trees civilized? Atlantic Mo. 138: 79–82. Jl 1926.

Knuth, R. Oxalidacearum species novae americanae. Repert. Spec. Nov. Fedde Veg. **23**: 138–144. 25 O 1926.

Lanham, W. B. Jujubes in Texas. Texas Agr. Exp. Sta. Circ. 41: 1–28. *f. 1–14.* Jl 1926.

Lauritzen, J. I. Infection and temperature relations of black rot of sweet potatoes in storage. Jour. Agr. Res. **33**: 663–676. *f. 1–4.* 1 O 1926.

Lauritzen, J. I., and Harter, L. L. The relation of humidity to infection of the sweet potato by *Rhizopus*. Jour. Agr. Res. **33**: 527–539. 15 S 1926.

Lee, H. A. The distribution of the roots of sugar cane in the soil in the Hawaiian Islands. Plant Physiol. **1**: 363–378. *f. 1–6.* O 1926.

Leonard, E. C. Notes on the genus *Sanchezia.* Jour. Washington Acad. Sci. **16**: 484–492. N 1926.
Several species described as new.

Leonian, L. H. The morphology and the pathogenicity of some *Phytophthora* mutations. Phytopathology **16**: 723–730. *f. 1–3* + *pl. 37.* 15 O 1926.

Lesley, J. W. The genetics of *Lycopersicum esculentum* Mill. I. The trisomic inheritance of "Dwarf." Genetics **11**: 352–354. *f. A–C.* "Jl" 24 D 1926.

Lesley, J. W. A study of resistance to western yellow blight of tomato varieties. Hilgardia **2**: 47–66. *f. 1.* S 1926.

Lesley, J. W., and Rosa, J. T. The improvement of tomatoes by selection. Hilgardia **2**: 25–45. *f. 1–9.* Au 1926.

Lesley, M. M. Maturation in diploid and triploid tomatoes. Genetics **11**: 267–279. *f. 1* + *pl. 1, 2.* "My" 19 O 1926.

Lindstrom, E. W. Hereditary correlation of size and color characters in tomatoes. Iowa Agr. Exp. Sta. Res. Bull. 93: 99–128. *f. 1–4.* Je 1926.

Lindstrom, E. W. Linked inheritance in tomatoes. Iowa S. Coll. Jour. Sci. **1**: 3–13. 1 O 1926.

Lindstrom, E. W. An unusual adaptation for cross-pollination. Jour. Hered. **17**: 232–234. *f. 1.* 8 S 1926.

Lipman, C. B., Davis, A. R., and West, E. S. The tolerance of plants for NaCl. Soil Sci. **22**: 303–322. O 1926.

Lipscomb, G. F., and Dowling, T. I. Factors that influence life and germination of cotton seed. Science II, **64**: 186–187. *illust.* 20 Au 1926.

Livingston, B. E., Hemmi, T., and Wilson, J. D. Growth of young wheat plants in auto-irrigated soils, as related to the water-supplying power of the soil and to the adjustment of the auto-irrigator. Plant Physiol. **1**: 387–395. *f. 1.* O 1926.

Lloyd, F. E. Maturation and conjugation in *Spirogyra longata.* Trans. Roy. Canad. Inst. **15**: 151–193. *pl. 1–4.* My 1926.

Lloyd, F. E. Studies on *Spirogyra.* I. Additional studies on conjugation. II. Adhesions and geniculations. Trans. Roy. Soc. Canada III, **20:** 75–110. *pl. 1.* 1926.

Lloyd, F. E. and Ulehla, V. The rôle of the wall in the living cell as studies by the auxographic method. Trans. Roy. Soc. Canada III, **20:** 45–73. 1926.

Lombard, L. H. Down deep. Am. Fern Jour. **16:** 95–97. 28 S 1926.

Fern species in a walled-up well.

Longley, A. E. Triploid citrus. Jour. Washington Acad. Sci. **16:** 543–545. 3 D 1926.

Loomis, W. E. The use of potassium oxalate as a deleading reagent. Plant Physiol. **1:** 403–407. O 1926.

Lutman, B. F. Respiration of potato tubers after injury. Bull. Torrey Club **53:** 429–455. 30 O 1926.

MacArthur, J. W. Linkage studies with the tomato. Genetics **11:** 387–405. "Jl" 24 D 1926.

McCallum, W. B. The botany and cultural problems of guayule. Ind. & Eng. Chem. **18:** 1121–1124. N 1926.

Parthenium argentatum.

MacDougal, D. T. The autobiography of trees. How trees are being made to write their own diaries. Am. For. & For. Life **32:** 661–662. *illust.* N 1926.

Contains an account of the dendrograph.

McGaffey, E. Denizens and dwellers of the desert. Nat. Mag. **8:** 293–294. *illust.* N 1926.

McHargue, J. S. Mineral constituents of the cotton plant. Jour. Am. Soc. Agron. **18:** 1076–1083. D 1926.

Macht, D. I. Concerning the influence of polarized light on the growth of seedlings. Jour. Gen. Physiol. **10:** 41–52. *f. 1–4.* 20 S 1926.

McKee, M. C., and Smith, A. H. Some nitrogenous constituents of the cauliflower bud. I. Protein fractions. Jour. Biol. Chem. **70:** 273–284. S 1926.

Mackenzie, K. K. Concerning *Solidago humilis*. Rhodora **28:** 208. "O" 6 N 1926.

Mackie, W. W., and Briggs, F. N. Effects of wheat treated with copper carbonate upon the common house mouse (*Mus musculus*). Phytopathology **16:** 629–632. *f. 1, 2.* 15 S 1926.

McKinney, H. H. Factors affecting the properties of a virus. Phytopathology **16:** 753. 15 O 1926.

McKinney, H. H. Virus mixtures that may be detected in young tobacco plants. Phytopathology **16:** 893. 15 N 1926.

McRostie, G. P., Hamilton, R. I., and Lundblad, N. O. Morphological similarities in alfalfa strains. Sci. Agr. **7:** 136–141. *pl. 1–7.* D 1926.

Mains, E. B. Studies in rust resistance. Jour. Hered. **17:** 313–325. *f. 1–6.* "S" 28 O 1926.

Maneval, W. E. Parasitic and wood-destroying fungi of Boone County, Missouri. Univ. Missouri Stud. **1:** 65–111. Ja 1926.

Martin, E. M. Cytological studies of *Taphrina coryli* Nishida on *Corylus americana*. Trans. Wisconsin Acad. Sci., Arts & Lett. **21:** 345–356. *pl. 12, 13.* 1924.

Martin, R. D. Study of off-type plants of Acala cotton. U. S. Dept. Agr. Circ. 390: 1–11. *pl. 1–5.* S 1926.

Mason, E. Treasures lost a hundred years. Nat. Mag. **9:** 33–35. *illust.* Ja 1927.

Mebane, W. M., and Vilbrandt, F. C. Classification of cotton by microscopy. Jour. Elisha Mitchell Sci. Soc. **42:** 122–125. O 1926.

Mellor, E. M. The countries our drugs come from. XIX. Mexico. Pharm. Jour. **117** (**IV, 63**)**:** 604–608. 20 N 1926.

Mendiola, N. B. Heritable characters of *Hibiscus*. I. Presence or absence of lobes on leaves of young plants. Philipp. Agr. **15:** 327–347. *illust.* N 1926.

Mercado, T. Study of the flowering habits and flower characteristics of three varieties of sugar cane. Philipp. Agr. **15:** 181–204. *illust.* S 1926.

Miller, E. V., and Hibbard, R. P. Aqueous extracts of seeds as agents in the preparation of silver sols. Plant Physiol. **1:** 409–413. O 1926.

Morgan, T. H. Genetics and the physiology of development. Am. Nat. **60:** 489–515. N–D 1926.

Morris, R. T. *Corylus pontica.* Addisonia **11:** 41–42. *pl. 373.* "S" 9 D 1926.
Native probably of Asia Minor.

Moss, E. H. The Uredo stage of the Pucciniastreae. Ann. Bot. **40:** 813–847. *f. 1–21 + pl. 34.* O 1926.

Mulvania, M. Studies on the nature of the virus of tobacco mosaic. Phytopathology **16:** 853–871. 15 N 1926.

Muncie, J. H. A study of the crown gall caused by *Pseudomonas tumefaciens* on rosaceous hosts. Iowa S. Coll. Jour. Sci. **1:** 67–110. *f. 1–7 + pl. 1–4.* 1 O 1926.

Murray, J. Mounting mosses as microscope slides. Bryologist **29:** 55–57. "S" 12 O 1926.

Neatby, K. W. Inheritance of quantitative and other characters in a barley cross. Sci. Agr. **7:** 77–84. *f. 1–8.* N 1926.

Newton, D. E. The distribution of spores of diverse sex on the hymenium of *Coprinus lagopus.* Ann. Bot. **40:** 891–917. O 1926.

Nichols, G. E. North American Arctic-alpine vegetation. Jour. New York Bot. Gard. **27:** 248–249. N 1926.
Abstract of a lecture.

Nolen, R. E. Pecan scab. Florida Agr. Exp. Sta. Bull. 181: 251–275. *f. 119–125.* My 1926.

Norton, A. H. Some botanical notes from the Andover meeting of the Josselyn Botanical Society. Maine Nat. **6:** 115–117. S 1926.

Ocfemia, G. O. Virus mixtures that may not be detected in young tobacco plants. Phytopathology **16:** 893–894. 15 N 1926.

Ocfemia, G. O., and Palo, M. A. The relation of certain Philippine commercial varieties of bananas to the wilt disease due to *Fusarium cubense* Efs. Philippine Agr. **15:** 243–244. S 1926.

Odell, W. S. List of mushrooms and other fleshy fungi of the Ottawa district. Mus. Bull. Victoria Mem. Mus. 43 (Biol. Ser. 11): 1–5. 22 Mr 1926.

O'Hanlon, Sister M. E. Germination of spores and early stages in development of gametophyte of *Marchantia polymorpha.* Bot. Gaz. **82:** 215–222. *pl. 12–15.* 28 O 1926.

Ohashi, H. *Oedogonium nebraskensis,* sp. nov. Bot. Gaz. **82:** 207–214. *f. 1–20.* 28 O 1926.

Palo, M. A. *Rhizoctonia* disease of rice. I. A study of the disease and of the influence of certain conditions upon the viability of the sclerotial bodies of the casual fungus. Philipp. Agr. **15:** 361–375. *pl. 1–4.* N 1926.

Parish, S. B. Notes on Cactaceae. Bull. So. California Acad. Sci. **25:** 83–84. S–D 1926.

Payson, E. B. *Thlaspi, Oreocarya* and *Erigeron.* Univ. Wyoming Publ. Sci. 1: 145–186. 1926.

Peattie, D. C. Asa Gray—botanist and educator. Nat. Mag. **8:** 303–304. *port.* N 1926.

Peattie, D. C. Indiana dune plant notes. Am. Midl. Nat. **10:** 129–132. N 1926.

Peattie, D. C. The need and making of local floras. Am. Bot. **32:** 142–146. O 1926.

Peattie, D. C. Nuttall, botanist and ornithologist. Nat. Mag. 9: 37–38. *port.* Ja 1927.

Peltier, G. L., King, C. J., and Samson, R. W. *Ozonium* root rot. U. S. Dept. Agr. Bull. 1417: 1–28. *f. 1, 2 + pl. 1–11.* Au 1926.

Pennell, F. W. Botanical travel in Peru and Chile. Jour. N. Y. Bot. Gard. **27:** 202–205. S 1926.
Abstract of a lecture.

Pennell, F. W. The elder Barton—his plant-collection and the mystery of his floras. Bartonia 9: 17–34. O 1926.
Benjamin Smith Barton, 1766–1815.

Peterson, W. H., Fred, E. B., and Marten, E. A. The effect of molecular complexity on the end-products formed by *Clostridium thermocellum.* Jour. Biol. Chem. **70:** 309–317. O 1925.

Petri, L. Anomalie di vegetazione e deperimenti delle viti innestate du piede americano. Boll. R. Staz. Patol. Veg. Rome. n.s. 6: 80–84. Ja 1926.

Pieters, A. J., and Monteith, J., Jr. Anthracnose as a cause of red-clover failure in the southern part of the clover belt. U. S. Dept. Agr. Farmers Bull. 1510: 1–17. *f. 1–11.* N 1926.

Pittier, H., and Killip, E. P. Venezuelan species of *Valeriana,* section *Porteria.* Jour. Washington Acad. Sci. **16:** 422–428. *f. 1* 19 S 1926.
V. foliosa, described as new.

Pomeroy, C. S. Two introduced plants of rare occurrence in the United States. Science II, **64:** 404–405. 22 O 1926.
Tagetes minuta and *Erodium cygonum.*

Popp, H. W. Effect of light intensity on growth of soy beans and its relation to the autocatalyst theory of growth. Bot. Gaz. **82:** 306–319. *f. 1–8.* 24 N 1926.

Pretz, H. W. A new station for *Serapias helleborine* L. Bartonia 9: 7–9. O 1926.
Riegelsville, Bucks County, Pennsylvania.

Proebsting, E. L. Structural weaknesses in interspecific grafts of *Pyrus.* Bot. Gaz. **82:** 336–338. *f. 1.* 24 N 1926.

Record, S. J. A new *Albizzia* of British Honduras. Yale Univ. School. For. Trop. Woods 8: 7. 1 D 1926.
A. Hummeliana.

Reddy, C. S., Holbert, J. R., and Erwin, A. T. Seed treatments for sweet-corn diseases. Jour. Agr. Res. **33**: 769–779. *f. 1–4.* 15 O 1926.

Rehder, A. *Monimopetalum*, a new genus of Celastraceae. Jour. Arnold Arbor. **7**: 233–234. "O" 24 D 1926.

Reid, M. E. Growth of tomato cuttings in relation to stored carbohydrate and nitrogeneous compounds. Am. Jour. Bot. **13**: 548–574. *pl. 38, 39.* 16 N 1926.

Rhine, J. B. Studies on the oxidation of certain fatty acids. Plant Physiol. **1**: 349–361. O 1926.

Rhine, J. B. Translocation of fats as such in germinating fatty seeds. Bot. Gaz. **82**: 154–169. 28 O 1926.

Rhoads, A. S. Observations on citrus wilt. Proc. Florida S. Hort. Soc. **38**: 26–39. "1925" 1926.

Ricker, P. L. Preserving our Christmas greens. Nat. Mag. **8**: 295–298. *illust.* N 1926.

Rickett, H. W. A quantitative study of the larger aquatic plants of Green Lake, Wisconsin. Trans. Wisconsin Acad. Sci. Arts & Lett. **21**: 381–414. *f. 1–7.* 1924.

Riker, A. J., and Keitt, G. W. Studies of crown gall and wound overgrowth on apple nursery stock. Phytopathology **16**: 765–808. *f. 1, 2 + pl. 38–47.* 15 N 1926.

Robbins, W. J. The isoelectric point for plant tissue and its importance in absorption and toxicity. Univ. Missouri Stud. **1**: 3–60. Ja 1926.

Robinson, B. L. Records preliminary to a general treatment of the Eupatoriaeae VI. Contr. Gray Herb. **77**: 1–62. 30 S 1926.

Robinson, T. R., and Savage, E. M. Pollination of the avocado. U. S. Dept. Agr. Circ. 387: 1–16. *f. 1–5.* Au 1926.

Rosen, H. R. Bacterial stalk rot of corn. Arkansas Agr. Exp. Sta. Bull. 209: 1–28. *pl. 1–3.* Jl 1926.

Rosen, H. R. The mosaic disease of sweet potatoes with special reference to its transmissibility. Arkansas Agr. Exp. Sta. Bull. 213: 1–16. *f. 1–4.* Au 1926.

Rosen, H. R. Negative results obtained by the use of paradichlorobenzene against the root-nematode, *Heterodera radicicola.* Phytopathology **16**: 635–636. 15 S 1926.

Rusby, H. H. Immunization against diseases produced by microscopical plants. Jour. N. Y. Bot. Gard. **27**: 227–231. O 1926.

Abstract of a lecture.

Russell, J. Plant nutrition and crop production. i–x, 1–115. *f. 1–37 + pl. 1–21.* Berkeley, Univ. Calif. Pr., 1926.

Rydberg, P. A. *Gaillardia amblyodon.* Addisonia **11**: 31–32. *pl. 368.* "Je" 13 O 1926.

Native of Texas.

Rydberg, P. A. Some extinct or lost and rediscovered plants. III. *Psoralea stipulata* T. & G. Torreya **26**: 86–89. 30 O 1926.

Sampaio, A. J. de. O limite inferior do reino vegetal e o valor taxinomico da reproduccao das plantas. Bol. Mus. Nac. Rio de Janeiro **2**: 47–88. *illust.* Mr 1926.

Santos, J. K. Histological study of the bark of *Alstonia scholaris* R. Brown from the Philippines. Philippine Jour. Sci. **31**: 415–425. *pl. 1–6.* N 1926.

Sargent, C. S. The Arnold Arboretum expedition to north central Asia. Jour. Arnold Arbor. **7**: 245–246. "O" 24 D 1926.

Contains letters from Mr. J. F. Rock.

Sargent, C. S. The trees at Mount Vernon. Ann. Rept. Mt. Vernon Ladies Assn. Union 1926: 1–16. My 1926.

Sawyer, M. L. Carpeloid stamens of *Podophyllum peltatum.* Bot. Gaz. **82**: 329–332. *f. 1–5.* 24 N 1926.

Sax, K. A genetical interpretation of ecological adaptation. Bot. Gaz. **82**: 223–227. 28 O 1926.

Sax, K. Sweet corn breeding experiments. Maine Agr. Exp. Sta. Bull. 332: 113–142. *f. 1–15.* My 1926.

Sayre, J. D. Physiology of stomata of *Rumex patientia.* Ohio Jour. Sci. **26:** 233–266. *f. 1–6.* 30 S 1926.

Scarth, G. W. The mechanism of accumulation of dyes by living cells. Plant Physiol. **1:** 215–229. Jl 1926.

Schafer, E. G., Gaines, E. F., and Barbee, O. E. Wheat varieties in Washington. Washington Agr. Exp. Sta. Bull. 207: 1–31. *f. 1–10.* Au 1926.

Schaffner, J. H. On the trail of *Equisetum* for four thousand miles. Am. Fern. Jour. **16:** 81–92. 28 S 1926.

Schaffner, J. H. A remarkable fern habitat. Am. Fern Jour. **16:** 79–81. *pl. 6.* 28 S 1926.

"Rock City," three miles southwest of Minneapolis, Ottawa County Kansas.

Schaffner, J. H. Siamese twins of *Arisaema triphyllum* of opposite sex experimentally induced. Ohio Jour. Sci. **26:** 276–280. *f. 1.* 30 S 1926.

Sconce, H. J. Constricted ears of maize. Jour. Hered. **17:** 257–260. *f. 9–11.* "Jl" 8 S 1926.

Setchell, W. A. Brief report of botanical work. The Tonga expedition of 1926. Science II, **64:** 440–441. 5 N 1926.

Setchell, W. A. Notes on *Microdictyon* II. Univ. California Publ. Bot. **13:** 147–153. 18 Au 1926.

Several species described as new.

Setchell, W. A. Phytogeographical notes on Tahiti. I. Land vegetation. II. Marine vegetation. Univ. California Publ. Bot. **12:** 241–324. 21 Au 1926.

Setchell, W. A. Townshend Stith Brandegee and Mary Katharine (Layne) (Curran) Brandegee. Univ. California Publ. Bot. **13:** 155–178. *pl. 13, 14.* 28 Au 1926.

Seward, A. The Cretaceous plant-bearing rocks of western Greenland. Phil. Trans. Roy. Soc. London **215:** 57–175. *f. 1 + pl. 4–12.* 1926.

Sharp, L. W. Introduction to cytology. 1–581. *f. 1–210.* New York, McGraw Hill, 1926.

Shay, A. The glorious Yucca. Nat. Mag. **9:** 21–22. *illust.* Ja 1927.

Sherff, E. E. *Cosmos Blakei*, a new species from Guatemala. Bot. Gaz. **82:** 333–335. *pl. 22.* 24 N 1926.

Sherwood, E. C. The nature of plant diseases. West Virginia Agr. Exp. Sta. Circ. 41: 1–35. *f. 1–42.* Je 1926.

Showalter, A. M. Studies in the cytology of the Amacrogynae. I. Antherozoids. II. Fertilization in *Riccardia pinguis.* III. Fertilization in *Fossombronia angulosa.* Ann. Bot. 40: 691–707; 713–726; **41:** 37–45. *f. 1–4 + pl. 24–27.* Jl; O 1926; Ja 1927.

Shull, G. H. "Old-gold" flower color, the second case of independent inheritance in *Oenothera.* Genetics **11:** 201–234. *pl. 1.* "My" 19 O 1926.

Small, J. K. An additional species of *Peperomia* from Florida. Torreya **26:** 109–110. 28 D 1926.
P. floridana.

Small, J. K. *Catharanthus roseus.* Addisonia **11:** 27–28. *pl. 366.* "Je" 13 O 1926.
Native of Madagascar?

Small, J. K. *Deeringothamnus pulchellus.* Addisonia **11:** 33–34. *pl. 369.* "S" 9 D 1926.
Native of southern peninsular Florida.

Small, J. K. The saw-palmetto *Serenoa repens.* Jour. N. Y. Bot. Gard. **27:** 193–202. *f. 1–4.* S 1926.

Small, J. K. Two new species from Florida. Torreya **26:** 91–93. 30 O 1926.
Lupinus Westiana and *Polygala aboriginum.*

Smith, C. P. Reviews of some perennial Lupines. I. Calcarati-Laxiflori. Am. Jour. Bot. **13:** 521–530. *f. 1, 2.* 16 N 1926.

Smith, E. F. Louis Pasteur. Nat. Mag. **8:** 346–347. *port.* D 1926.

Smith, E. F. William Edwin Safford. Jour. Hered. **17**: 366–367. 27 N 1926.
Born 14 D 1859. Died 10 Ja 1926.

Smith, G. H. Vascular anatomy of Ranalian flowers. I. Ranunculaceae. Bot. Gaz. **82**: 1–29. *f. 1–34.* 30 S 1926.

Smith, H. H. A European botanical trip. Yearbook Public Mus. Milwaukee **4**: 67–94. *illust.* O 1926.

Snow, L. M., and Fred, E. B. Some characteristics of the bacteria of Lake Mendota. Trans. Wisconsin Acad. Sci., Arts & Lett. **22**: 143–154. *pl. 4.* 1926.

Sommer, A. L., and Lipman, C. G. Evidence on the indispensable nature of zinc and boron for higher green plants. Plant Physiol. **1**: 231–249. *f. 1–13.* Jl 1926.

Spaulding, P. The white pine blister rust in Germany. Jour. For. **24**: 645–652. O 1926.

Spaulding, P., and Rathbun-Gravatt, A. The influence of physical factors on the viability of sporidia of *Cronartium ribicola.* Jour. Agr. Res. **33**: 397–433. *f. 1–17.* 1 S 1926.

Spegazzini, C. *Banara glandulosa* (Dsvx.) Speg. Rev. Argentina Bot. **1**: 205–210. *illust.* Mr 1926.

Spegazzini, C. *Calliandras* argentinas. Rev. Argentina Bot. **1**: 180–199. Mr. 1926.
C. brachyandra described as new.

Spegazzini, C. Noticias interesantes relativas a algunos *Tephrocactus.* Rev. Argentina Bot. **1**: 200–204. *illust.* Mr 1926.

Spegazzini, C. Nuevo caso de intoxicacion por hongos frescos indigenas. Rev. Argentina Bot. **1**: 231–233. *illust.* Mr 1926.
Armillaria ameghinoi.

Spegazzini, C. Nuevo depósito de *Araucarites mirabilis* Speg. Rev. Argentina Bot. **1**: 238–239. Mr 1926.

Spegazzini, C. Probable segunda especie de *Chiovenda.* Rev. Argentina Bot. **1**: 228–230. Mr 1926.

Spegazzini, C. Ramillete patagónico. Rev. Argentina Bot. **1**: 211–227. Mr 1926.
Verbena macrosperma and *Boopis Raffaellii* described as new.

Spegazzini, C. Las victimas de la *Araujoa sericifera* Brot. Rev. Argentina Bot. **1**: 177–179. Mr 1926.

Spegazzini, C. Violetas argentinas. Rev. Argentina Bot. **1**: 234–237. Mr 1926.

Sprague, T. A. Sessé and Mociño's Plantae novae hispaniae and Flora Mexicana. Kew Bull. Misc. Inf. **1926**: 417–425. 1926.

Stancliff, J. O. Breadfruit. Am. Bot. **32**: 140–142. O 1926.

Standley, P. C. The Costa Rican species of *Ilex*. Jour. Washington Acad. Sci. **16**: 481–484. 3 N 1926.
3 species described as new.

Standley, P. C. The flora of Venezuela. Bull. Pan-Am. Union **60**: 978–990. *illust.* O 1926.

Standley, P. C. The genus *Calatola*. Jour. Washington Acad. Sci. **16**: 413–418. *f. 1.* 19 S 1926.
C. costaricensis, described as new.

Standley, P. C. Three new species of Central American trees. Yale Univ. School For. Trop. Woods **8**: 4–6. 1 D 1926.
Vitex Kuylenii, *Protium asperum* and *Bourreria mollis*.

Standley, P. C. Trees and shrubs of Mexico (Bignoniaceae-Asteraceae). Contr. U. S. Natl. Herb. **23**: 1313–1721. 15 N 1926.

S[tapf], O. *Mammillaria conopsea*. Curt. Bot. Mag. **151**: *pl. 9101.* 21 Je 1926.
Native of Mexico.

S[tapf], O. *Rhodospatha Forgetii*. Curt. Bot. Mag. **151**: *pl. 9105.* 21 S 1926.
Native of Costa Rica.

S[tapf], O. *Spiranthes Pamii*. Curt. Bot. Mag. **151**: *pl. 9094.* 21 Je 1926.
Native of Argentina.

Stason, M. The Marsileas of the western United States. Bull. Torrey Club **53:** 473–478. 30 O 1926.

Steinbauer, G. Differences in resistance to low temperatures shown by clover varieties. Plant Physiol. **1:** 281–286. *f. 1, 2.* Jl 1926.

Stevens, F. L. Corrugated aluminum sheets for the botanist's press. Bot. Gaz. **82:** 104–106. *f. 1, 2.* 30 S 1926.

Stevens, N. E. Occurrence of the currant cane blight fungus on numerous hosts in the southern states. Mycologia **18:** 278–282. *f. 1.* 1 N 1926.

Stewart, F. C. The mica ink-cap, or glistening *Coprinus*. New York (Geneva) Agr. Exp. Sta. Bull. 535: 1–30. *pl. 1, 2.* Jl 1926.
C. micaceus.

Stout, A. B. The capsules, seeds and seedlings of the orange day lily. Jour. Hered. **17:** 243–249. *f. 1–5.* "Jl" 8 S 1926.

Stout, A. B. The international conference on flower and fruit sterility. Jour. N. Y. Bot. Gard. **27:** 209–210. S 1926.

Stout, A. B., and Savage, E. M. The flower behavior of avocados with special reference to interplanting. Proc. Florida S. Hort. Soc. **38:** 80–91. "1925" 1926.

Sudworth, G. B. Technical name of sugar maple. Rhodora **28:** 179. 20 S 1926.
Disagrees with Mr. Mackenzie's discarding *Acer saccharum* for *A. saccharinum.*

Sugata, H., and Koch, F. C. Sulphur metabolism of yeast. Plant Physiol. **1:** 337–347. O 1926.

Taubenhaus, J. J. Studies of a new *Fusarium* wilt of spinach in Texas. Texas Agr. Exp. Sta. Bull. 343: 1–23. *f. 1–6.* Jl 1926.
F. solani.

Tetrault, P. A. Bacterial spores for class work. Proc. Indiana Acad. Sci. **35:** 213–214. *f. 1.* "1925" 1926.

Thompson, R. C. Tipburn of lettuce. Colorado Agr. Exp. Sta. Bull. 311: 1–31. *pl. 1–5.* My 1926.

Thompson, W. P. Chromosome behavior in a cross between wheat and rye. Genetics **11:** 317–332. *f. 1–9.* "Jl" 24 D 1926.

Thone, F. Plant physiology at the Ithaca Congress. Plant Physiol. **1:** 293–305. *illust.* O 1926.

Tisdale, W. B., and Kelley, J. G. Stem injury of tobacco caused by fungi growing on the poison mixture used for controlling budworms. Florida Agr. Exp. Sta. Bull. 182: 279–286. *f. 126–131.* My 1926.

Tompkins, C. M. Influence of the environment on potato mosaic symptoms. Phytopathology **16:** 581–610. *f. 1–6 + pl. 28–32.* 15 S 1926.

Toro, R. A. [Dr. Carlos Spegazzini.] Mycologica **18:** 284. 1 N 1926.
Born 20 Ap 1858. Died 1 July 1926.

Torrey, R. H. The survival and protection of harried flowers. Jour. N. Y. Bot. Gard. **27:** 217–223. O 1926.
Abstract of a lecture.

Tottingham, W. E. The chemical analysis of plant tissues. Plant Physiol. **1:** 397–402. O 1926.

Tottingham, W. E. Temperature effects in the metabolism of wheat. Plant Physiol. **1:** 307–336. *f. 1–3.* O 1926.

Tottingham, W. E., and Kerr, H. W. Climatic effects in the metabolism of maize. Plant Physiol. **1:** 415–416. O 1926.

Trelease, S. F., and Trelease, H. M. Relation of temperature to the physiological values of salt solutions as indicated by growth of wheat roots. Bull. Torrey Club **53:** 605–609. "N" 29 D 1926.

Trelease, W. Piperaceae cubenses. Repert. Spec. Nov. Reg. Veg. **23:** 1–31. 1 Au 1926.

Trudell, H. W. "Rescuing Elliottia." Bartonia 9: 11–15. O 1926.
Elliottia racemosa.

Trudell, H. W., and Pennell, F. W. Alexander MacElwee. Bartonia 9: 1–6. *port.* O 1926.
Born 28 Ja 1869. Died 23 Ja 1923.

Tullis, M. P. Weeds, their identification and control. (5th ed. revised and enlarged). Bull. Dept. Agr. Saskatchewan 47: 1–88. *illust.* 1926.

Uphof, J. C. T. Protection of the *Tumion* in Florida. Science II, **64**: 405. 22 O 1926.

Urban, I. Plantae Haitienses novae vel rariores. II, III. a cl. E. L. Ekman 1924–1926 lectae. Arkiv Bot. **20A**^{5}: 1–65; **20A**^{15}: 1–94. *f. 1, 2 + pl. 1–3.* 16 Ap; 9 D 1926.

Valleau, W. D. Root troubles, a cause of early death of apple trees. Trans. Kentucky S. Hort. Soc. 1925: 141–155. 1926.

Valleau, W. D., Karraker, P. E., and Johnson, E. M. Corn root rot—a soil-borne disease. Jour. Agr. Res. **33**: 453–476. *f. 1–10.* 1 S 1926.

Van der Meer, J. H. H. Verticillium-wilt of maple and elm-seedlings in Holland. Phytopathology **16**: 611–614. *f. 1 + pl. 33.* 15 S 1926.

VanHook, J. M. *Gloeosporium hysterioideum* Dear. & Barth.—a leaf disease of *Acer saccharum* Marsh. Proc. Indiana Acad. Sci. **35**: 232–233. "1925" 1926.

VanHook, J. M. Indiana fungi IX. Proc. Indiana Acad. Sci. **35**: 233–236. "1925" 1926.

VanHook, J. M. A new species of *Graphium.* Proc. Indiana Acad. Sci. **35**: 231. "1925" 1926.
G. hamamelidis.

Vibar, T. The relation of temperature and moisture to diseased and disease-free corn. Philippine Jour. Sci. **31**: 169–213. *f. 1–11 + pl. 1.* O 1926.

Vinall, H. N. A method of crossing sorghums. Jour. Hered. **17**: 297–300. *f. 9–11.* "Au" 9 O 1926.

Waite, M. B., Gilbert, W. W., Cobb, N. A., Beattie, W. R., Brooks, F. E., Graf, J. E., Bell, W. B., and McAtee, W. L. Diseases and pests of fruits and vegetables. U. S. Dept. Agr. Agr. Yearbook **5**: 453–599. *f. 202–293.* Jl 1926.

Walker, J. C. The influence of soil temperature and soil moisture upon white rot of *Allium.* Phytopathology **16:** 697–710. *pl. 34, 35.* 15 O 1926.

Walker, J. C. On the nature of disease resistance in plants. Trans. Wisconsin Acad. Sci., Arts & Lett. **21:** 225–247. 1924.

Weaver, J. E. Root development of field crops. i–xii, 1–291. N. Y. McGraw Hill Co., 1926.

Webb, R. W., and Fellows, H. The growth of *Ophiobolus graminis* Sacc. in relation to hydrogen-ion concentration. Jour. Agr. Res. 33: 845–872. *f. 1–8.* 1 N 1926.

Wehmeyer, L. E. Cultural life histories of *Melanconis* and *Pseudovalsa.* Mycologia **18:** 257–273. *pl. 30–33.* 1 N 1926.

Weimer, J. L. A leaf spot of cruciferous plants caused by *Alternaria herculea.* Jour. Agr. Res. **33:** 645–650. *f. 1* + *pl. 1–2.* 1 O 1926.

Weir, J. R. Observations on *Calyptospora columnaris* and *Peridermium ornamentale.* Mycologia **18:** 274–277. *pl. 34, 35.* 1 N 1926.

Welch, W. H. An ecological study of the flora of Fountain Park and portions of the adjacent territory, Jasper County, Indiana. Proc. Indiana Acad. Sci. **35:** 201–212. *map.* "1925" 1926.

Wentz, J. B. Heritable characters of maize. XXVI—Concave. Jour. Hered. **17:** 327–329. *f. 7, 8.* "S" 28 O 1926.

Wetmore, R. H. Organization and significance of lenticels in dicotyledons. I. Lenticels in relation to aggregate and compound storage rays in woody stems. Lenticels and roots. II. Lenticels in relation to diffuse storage rays of woody stems. Bot. Gaz. **82:** 71–88, 113–131. *pl. 5–10.* 30 S; 28 O 1926.

Wharton, M. The western myrtle. Am. For. & For. Life **32:** 659–660. *illust.* N 1926.
Umbellularia californica.

Wherry, E. T., and Gray, F. W. The West Virginia locality of the southeastern relative of *Woodsia scopulina.* Am. Fern Jour. **16:** 92–95. *pl. 7.* 28 S 1926.
2½ miles northwest of Sweet Springs.

White, C. T. A new species of *Paramignya* from Papua with notes on two other Papuan Rutaceae. Jour. Arnold Arbor. **7:** 231–233. 24 D 1926.
P. Brassii.

Whiting, A. L., Fred, E. B., and Helz, G. E. A study of the root-nodule bacteria of Wood's clover (*Dalea alopecuroides*). Soil Sci. **22:** 467–476. *pl. 1, 2.* D 1926.

Wiggans, R. G. Method now employed in testing F_1 corn hybrids at the Cornell University Agricultural Experiment Station. Jour. Am. Soc. Agron. **18:** 794–798. S 1926.

Williams, R. S. *Ginkgo biloba.* Addisonia **11:** 19–20. *pl. 362.* "Je" 13 O 1926.
Native probably of China.

Willis, J. C. Age and area. Quar. Rev. Biol. 1: 553–570. *f. a, b.* O 1926.

Wilson, E. H. Magnoliaceae collected by J. F. Rock in Yunnan and Indo-China. Jour. Arnold Arbor. **7:** 235–239. "O" 24 D 1926.

Wilson, E. H. *Taiwania cryptomerioides hayata.* Jour. Arnold Arbor. **7:** 229–231. *pl. 3.* "O" 24 D 1926.

Wodehouse, R. P. Pollen grain morphology in the classification of the Anthemideae. Bull. Torrey Club **53:** 479–485. *f. 1–2.* 30 O 1926.

Wolf, F. A. Brown leafspot of leather-leaf fern. Jour. Elisha Mitchell Sci. Soc. **42:** 55–61. *pl. 1, 2.* O 1926.

Wolf, F. A. The perfect stage of the fungus which causes melanose of *Citrus.* Jour. Agr. Res. **33:** 621–625. *f. 1, 2.* 1 O 1926.

Wolf, F. A. Something new about melanose. Proc. Florida S. Hort. Soc. **39:** 153–154. "1925" 1926.
Diaporthe citri, ascogenous stage of fungus.

Wolfe, H. S. Absorption of water by barley seeds. Bot. Gaz. **82**: 89–103. *f. 1.* 30 S 1926.

Wolfe, H. S. Surface forces of soils within the range of hygroscopic moisture. Bot. Gaz. **82**: 195–206. *f. 1.* 28 O 1926.

Woodring, W. P. How fossils got into the rocks. Sci. Mo. **23**: 337–345. *illust.* O 1926.

Woodroof, J. G., and Woodroof, N. C. Fruit-bud differentiation and subsequent development of the flowers in the *Hicoria* pecan. Jour. Agr. Res. **33**: 677–685. *f. 1–7.* 1 O 1926.

Wynd, F. L. Further notes on *Cynosurus echinatus* L. in Oregon. Torreya **26**: 89–91. 30 O 1926.

York, H. H. A Peridermium new to the northeastern United States. Science II, **64**: 500–501. 19 N 1926.
On *Pinus sylvestris* at Woodgate, New York.

Young, P. A. Facultative parasitism and host ranges of fungi. Am. Jour. Bot. **13**: 502–520. *pl. 36, 37.* 15 O 1926.

Zeller, S. M. A blossom and spur blight of pear caused by a strain of *Botrytis cinerea* Pers. Jour. Agr. Res. **33**: 477–482. *f. 1–4.* 1 S 1926.

Zeller, S. M. The brown-pocket heart rot of stone-fruit trees caused by *Trametes subrosea* Weir. Jour. Agr. Res. **33**: 687–693. *f. 1, 2.* 1 O 1926.

Zeller, S. M. Species of *Nectria*, *Gibberella*, *Fusarium*, *Cylindrocarpon* and *Ramularia* occurring on the bark of *Pyrus* spp. in Oregon. Phytopathology **16**: 623–627. *f. 1–3.* 15 S 1926.
Cylindrocarpon angustum described as new.

Studies on morphogenesis and development of the ascocarp of Sphaerotheca castagnei

ILLO HEIN

(WITH FIVE TEXT FIGURES AND PLATES 28, 29)

The structure of the ascocarp and the stages in its development have been fairly well understood since the time of De Bary, and the main points in his conclusions have been many times confirmed. The perithecial tissues are formed by aggregation of hyphae. De Bary characterized such structures as pseudoparenchymatous, and the term has been generally accepted. Little attempt has been made, however, at a morphogenetic analysis of the various growth factors, the hyphal contacts and pressures and the environmental stimuli by which the development of such structures is initiated and controlled.

LITERATURE

The literature concerning the morphology and development of the ascocarp of the mildews has been many times reviewed and analysed. I shall endeavor to summarize the data which relate to my own special problems under the following heads: (1) Pseudoparenchyma, morphogenesis, and tropistic responses; (2) Physiological species in the mildews; (3) Spore discharge; (4) Epiplasmic granules in the ascus.

Pseudoparenchyma, morphogenesis, and tropistic responses. The development of parenchyma-like tissue from filamentous hyphae was first studied by De Bary (1863, 1870) in *Erysiphe* and in *Eurotium* and by Woronin (1869–70) in *Sordaria*. De Bary described in some detail the formation of such pseudoparenchymatous tissue in the development of the perithecia of *Podosphaera tridactyla*, *Sphaerotheca castagnei* and in *Eurotium glaucum*. As is well known for ascomycetes generally the ascogonium becomes covered with an inner and an outer layer of parenchyma-like tissue which is formed by the growth, branching, and interweaving of hyphae. The hyphae divide only by transverse septa

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and ultimately fill in all inter-hyphal spaces, forming an unbroken tissue. Bauke (1876) distinguished three methods of pycnidial development to which Zopf (1881) gave the names, "Hyphenfrucht," "Gewebefrucht," and "Knäulfrucht." It has been claimed by De Bary (1884), von Tavel (1886), Schnegg (1915), and Kempton (1919), and others that the walls of certain pycnidia develop by division in three planes (meristogenetic) while others are formed symphyogenously by the interweaving of hyphae and hence consist of pseudoparenchyma. The "Hyphenfrucht" and "Gewebefrucht" of Bauke and Zopf are variations of De Bary's meristogenic types. Kempton (1919) concludes that the meristogenous method is the more common and is of two types, simple and compound, while the syphyogenous method is less often found.

Hoffman (1856), Hartig (1874), Göbel (1902), Fayod (1889), and many other later students have reported detailed studies of the morphology, growth, and development of the fleshy fungi but have taken little account of the morphogenetic factors involved.

From a study of *Agaricus campestris*, W. Magnus (1906) concludes that certain specific, organized parts of the pseudoparenchyma create growth inhibitions against the organism as a whole, so that certain tissues of the sporocarp give rise in regeneration to similar tissues only; for example, the hymenium can give rise only to hymenial tissue. The regeneration of a normally lamellate hymenium may result, however, in a decidedly toothed, tubular or netlike hymenium. This condition is not to be regarded as atavistic in the Weismann sense, even though such forms are according to present phylogenetic views lower, but is due to the mechanical conditions under which the regenerative growth takes place. Transformation of vegetative to reproductive tissue results in a loss of the capacity for regenerating the whole sporocarp. So long as the tissue is still vegetative it possesses in a high degree the capacity to regenerate itself, but at a certain stage it becomes reproductive and loses its capacity for regeneration. W. Magnus also holds that the exhaustion of foodstuffs in the substratum as well as the transition to aerial growth must be of importance in determining the initiation of sporocarp formation. That the transition to an aerial environment is insufficient, as W. Magnus notes, to cause sporocarp development is shown by the fact that in dark, poorly ventilated cellars the mycelium may grow upon the surface of the substratum for days without producing sporocarps. Mere transition from growth below the substratum to aerial growth does not suffice to initiate the development of fruit. Similar conditions were observed under bell jars placed over cultures. The hyphae grew profusely under the bell jars without producing sporocarps, while immediately outside the jars numerous sporocarps developed. Light seems to be unnecessary for the development of *Agaricus campestris*, growth and differentiation going on equally well in darkness.

Atkinson (1906) recognizes certain factors in the development of the pileus of *Agaricus campestris* as follows: "The growth of the pileus which at first is strongly hyponastic becomes less so as the pileus expands. The upper surface gradually ceases to grow and the extension of the underlying part often tears the cuticle of the pileus into fibrous scales. The growth of the pileus gradually becomes epinastic, as the lower area and the hymenophore with the gills now grow more rapidly than the middle and upper portions. This causes the pileus to become plane, or in old specimens the margin itself becomes upturned." De Bary had already described the later growth stages of the pileus as epinastic.

The geotropic responses of the sporocarps, as they occur in nature, have long been known. Brefeld (1883), Buller (1909), and W. Magnus (1906) have reported important experimental results on the geotropic and heliotropic behavior of many species. Buller (1909) reports that the stipe is indifferent to geotropic stimuli before the pileus is developed, after which it becomes positively heliotropic and rectipetal in darkness. Buller states that the position of the gills is always very delicately adjusted by geotropic stimuli. The positively geotropic response is of great importance for successful spore liberation, since these are discharged by dropping downwards and easily lodge on the gill lamellae if the latter are not exactly vertical.

In petri dish cultures of *Lasiobolus pulcherrimus* Delitsch (1926) finds that the main hyphae of the mycelium grow radially from the spore, and the secondary directions of growth are thought to be determined largely by the tendency of the hyphae to enter areas unoccupied by other hyphae.

Physiological species in the mildews. Apparently P. Magnus (1898) first published the results of infection experiments with parasitic Erysiphaceae. P. Magnus reported the transfer of *Sphaerotheca castagnei* (Lev.) from the hop to *Taraxacum officinale* but his results were not confirmed by Neger (1902). Salmon (1904, 1907) found that *Sphaerotheca humuli* from *Potentilla reptans* would not infect *Agrimonia Eupatoria*, *Alchemilla arvensis*, *A. vulgaris*, *Fragaria*, *Poterium officinale*, or *Spirea ulmaria*, all of which are hosts for *Sphaerotheca*. *Sphaerotheca humuli* var. *fuliginea* from *Plantago lanceolata* would not infect *P. major* or *Taraxacum officinale;* and *Sphaerotheca humuli* var. *fuliginea* from *Taraxacum* would not infect *Fragaria*, *Plantago media*, or *P. lanceolata*, all of which are hosts of morphologically similar forms of *Sphaerotheca humuli.*

Steiner's (1908) results from experiments with *Sphaerotheca humuli* within one host genus, *Alchemilla*, led him to assume the existence of "kleine biologische Arten." Reed (1908) has summarized the literature of inoculation experiments with the mildews and states that in his opinion most of the results rest upon inadequate data. Woronichine (1914) failed to obtain infection on peach leaves with *Sphaerotheca pannosa* from the rose and failed also in the reciprocal experiment, though the forms on both plants are morphologically indistinguishable.

De Bary's morphological work on *Sphaerotheca castagnei* was done on material from *Taraxacum officinale.* Harper (1895) and Dangeard (1896) worked on material from the hop, and Winge (1911) worked on a *Sphaerotheca* from *Melampyrum* in Sweden. It would appear probable from the studies noted that there are many physiologically different races of *Sphaerotheca* as well as of other mildews, and Gäumann's work on other fungi suggests the possibility that there may be structural differences paralleling the physiological specificities.

Spore discharge. In *Sphaerotheca* and the other mildews spore discharge involves, first, the rupture of the cleistocarp and, second, the escape of the spores from the ascus. The rupture of the cleistocarp was first described for the Erysiphaceae by Wolff (1872), later by Smith (1884) for *Erysiphe graminis*, and by Salmon (1903) for *Sphaerotheca.* The mechanism of discharge from the ascus has been frequently reported on for the club-shaped asci and has been fully described by Buller (1909) for a number of forms. De Bary states that in the Erysipheae spore discharge is simultaneous. Wolff (1877) finds that in *Erysiphe* the spores are liberated through a longitudinal slit in the apex of the ascus. Smith (1884) found that in *Erysiphe graminis* spores and sometimes asci are ejected forcibly from the ascocarp. Salmon (1907) describes the process as observed in *Erysiphe graminis*. The spores after the ascocarp has undergone a resting period are ejected forcibly into the air to a distance of 2 cm. from the ascocarp. According to Salmon the perithecium opens by a horizontal slit at one side somewhere about the equatorial plane. This slit gradually extends until the upper half is set free like a lid. Salmon states that the dehiscence is probably brought about by the swelling of the inner layer of the perithecial cells. In *Sphaerotheca* a vertical slit appears in the perithecium and the ascus protrudes from it, swelling to several times the diameter of the perithecium. The walls of the ascus become tense, the ascospores collect at the apex, and are finally discharged forcibly through a slit. Occasionally an ascus slips out of the perithecium, ultimately bursting to discharge the spores. Recently Ziegenspeck (1926) has given an adequate review of the literature and has made a detailed study of spore discharge of many different forms of Ascomycetes, but no data as to spore discharge in the Erysiphaceae are given.

Epiplasmic granules in the ascus. Most of the literature has been summarized by Guilliermond (1904) and by Pénau (1912). Zopf (1887) described disc-shaped granules and granules of variable shapes, generally six to eight microns in greatest diameter, in the conidia, conidiophores, and germ tubes of species of *Erysiphe*, *Podosphaera*, and *Sphaerotheca* which he believed to be reserve carbohydrates and called "Fibrosinkörper." Maire (1905) described metachromatic granules in Ascomycetes and Basidiomycetes and believed them to be not particular kinds of granules, but granules belonging to the vast class of Altmann's granules which are very variable chemically, depending on the species of plant in which they occur.

The granules described by Guilliermond (1904) in the epiplasm and the sporeplasm of *Aleuria cerea*, *Helvella sulcata*, *Ciboria uliginosa*, *Pustularia vesiculosa*, *Otidea onotica*, *Peziza venosa*, and other *Peziza* species stain bright red with Unna's polychrome blue after fixation with picroformol. Hemalum gives clear differentiation of the granules with alcohol as a fixative, but is very poor when used with picroformol.

Meyer (1904) describes, in *Penicillium glaucum*, *Aspergillus glaucus*, and the Basidiomycetes, algae, gymnosperms, and angiosperms, granules, similar to those which he earlier described in bacteria and called volutin. In unstained living *Penicillium* and in *Aspergillus* the granules can be recognized only with difficulty but with methylene blue (1 to 10) they stain dark blue in color, darker than any other parts of the cell. With carbol fuchsin the granules stain a deep red color. Delafield's haematoxylin (10 drops in 5 cc. water) produces a dark blue color when the granules are treated with carbolic acid, but when Flemming's fixative is used pale-blue stained granules result. Fresh material, as well as material treated with formalin plus 3 per cent acetic acid, when stained with alcoholic or aqueous solution of ruthenium red gives red-brown colored granules. Meyer states that the granules are present in all parts, from the germinating conidium to the newly produced spore of the vegetative plant of *Penicillium glaucum*, but their occurrence in the ascus is not mentioned.

OBSERVATIONS

The development of a three or more layered pseudoparenchyma of cells progressively differentiated from the surface inward and enclosing a single large cell, the ascus, as we find it in *Sphaerotheca*, or a group of such cells as in *Erysiphe*, may be regarded as typical for all the powdery mildews.

The mycelium

The general facts as to spore germination and the nature of the mycelium are well known but may be reviewed briefly as an introduction to the problems involved in the formation of the pseudoparenchymatous perithecium. The conidia on germinating give rise, generally at somewhat equal distances and in a horizontal plane, to three or four hyphae which grow out at right angles to the ellipsoid spore. At first the growth is very irregular but later tends more to be radial from the spore as a center. The hyphae are at first thick and tend to be nodular. Later they become more evenly filamentous in form (text figure 1, *1* and *2*). The patches of mildew generally are circular in outline, and examination with the lens shows that the general direction of growth of the hyphae is radially from the center. The mycelium is profusely branched, septa occur fairly regularly, and the cells are from 40 to even 80 microns in length. The average length of the mycelial cells is about 55 microns, which is similar to the average given by Bezssonoff (1914) for the mycelial cells of *Sphaerotheca mors uvae*, which he states are 57.6 by 5.4 microns. Where the mycelial network is especially well developed, septa are frequently rather close together, so that some cells are but 10, 15 or 20 microns long. The first septum is often formed a short distance, one to three microns, from the spore (text figure 2, *3*). The hypha stains pale blue with the triple stain and Allen-Bouin fixation, while the cytoplasm of the spore stains a darker blue.

The factors determining the distribution of the mycelium include (1) those concerned with the general radial distribution of the hyphae about the spore; (2) those which determine their contact relations with the host surface; (3) those which determine the angles that the successive sets of branches make with each other.

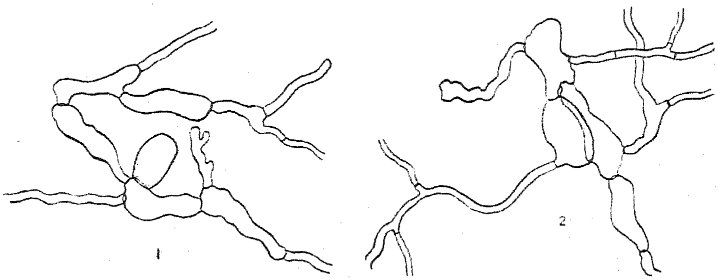

Fig. 1. *1* and *2*. Germinating conidia with characteristic irregular, gnarled germ-tubes and radially growing mycelium.

As noted, the spore on germinating sends out from one (text figure 1, *1*) to three (text figures 1,*2* and 2,*3*) germ tubes, some of which may be very stout, gnarled, irregularly shaped structures from which other similar irregular hyphal branches or the characteristic mycelium may arise (text figure 1, *1* and *2*). A hyphal complex is thus formed; and about this there is a somewhat radial orientation of the profusely branched hyphae. The branches may arise either slightly below the septum or nearly midway between two septa. The problems as to the direction of growth and method of branching of the hyphae here are essentially similar to those involved in the distribution of roots and branches in the higher plants. Chemotropic stimuli depending on the distribution of the food supply may be significant in determining the distribution of the ultimate hyphal branches. Whether moisture in hygroscopic relations or contact in thigmotropic relations determine the close adhesion of the hyphae to the host leaf is not easy to determine. The appresoria from which the haustoria arise are adhesion organs, and it seems probable that in some degree their development is regulated by tactic stimuli.

A fact that tends to support the assumption of hygromorphoses on the part of the hyphae is the very frequently profuse growth of the fungus in the grooves formed along the juncture of veins and leaf lamina.

In field plants the mildew first makes its appearance on the under surface of the leaves, where because of shade, more numerous stomata, and thinner cuticle the vapor pressure in the thin film of atmosphere immediately surrounding the leaf is probably higher than on the upper surface. In green-houses, where the absence of strong air currents tends to permit greater vapor pressure on both leaf surfaces, and where the general atmosphere tends to be more moist, the difference in vapor pressure between upper and lower surfaces may be less important. On green-house plants the mildew generally appears first on the upper leaf surfaces, perhaps because more spores lodge there and, finding favorable conditions, germinate and grow in situ. Eventually in the green-house the mildew also appears on the under surface of the leaf. The whole complex of factors influencing infection probably favor the under side of the leaf in field plants and the upper side in green-house plants.

That the mycelial hyphae may be reciprocally negatively chemotropic is to be considered. From his observations on *Lasiobolus pulcherrimus* grown on solid media in petri dishes Delitsch (1926) holds that the growth form of the mycelium is due to the dominately radial growth in the main hyphae and to mutually repellant chemotropic influence between all hyphae. Müller (1922), from observations made on the *Saprolegniaceae*, also suggests negatively chemotactic response as causing hyphae to grow apart from one another.

After the infected area is older, the later formed hyphal branches grow in all directions, filling in unoccupied areas. The typical radial distribution may be based on morphaethesia in Nöll's (1900) sense—that is, "Empfindungsvermögen für Form und Lage des eigenen Körpers." The deviation from the typical will be the result of various morphotic responses in Pfeiffer's (1925) sense.

Development of the primary envelope (cortical layers of the perithecium)

The term *perithecium*, though loosely used to designate the entire fructification, asci, enclosing envelope, etc., is properly used to designate only the enclosing hyphal layers, whereas the whole fructification is the *ascocarp*. I shall distinguish the outer protective cell layers as the cortex to distinguish them from the inner nutritive zone.

While the data are fragmentary and the methods of morphogenetic analysis for the thallophytes are as yet very poorly developed, it would seem that with the mass of structural and morphological material already at hand a beginning in the attempt to recognize the form-determining stimuli in the case of the ascocarp should be made. The work of W. Magnus (1906) and of Buller (1905) on the carpophore of the Basidiomycetes is suggestive of what can and should be done for the Ascomycetes.

The ascocarp begins its development after fertilization has been accomplished. There can be no question that the ascocarp is, however, strictly gametophytic in its origin. Brefeld's (1883) and Dangeard's (1896) contention that the sex cells are not functional has failed of confirmation so far, but in any case there is no doubt as to the relations of the gametophyte and sporophyte in the makeup of the ascocarp.

The enveloping hyphae arise just below the septum which cuts off the oogone from the basal cell and at a corresponding level from the basal cell of the antherid. These enveloping hyphae closely follow the contour and direction of growth of the ascogone rather than that of the antheridial stalk cell. The stalk cell of the latter forms one of the series of enveloping elements. This discriminitive relation in the behavior of the enveloping hyphae with reference to the sex elements becomes more and more emphasized as the primary layer develops. Harper (1905) shows that the antheridial cell in *Phyllactinia* becomes embedded in the layers of the perithecium, where it ultimately gelatinizes and degenerates. In the *Sphaerotheca* here described, the antherid and its stalk cell become a permanent part of the primary envelope, in which they may be readily distinguished from the hyphal cells (figure 19). In late stages the antherid and the stalk cell cannot be identified with certainty. In all probability these cells have expanded laterally during the distention phase of the perithecium and have come to resemble closely the other cells. The special relations of the enveloping hyphae to the oogone suggest the existence of chemical stimuli with close adhesion phenomena due perhaps to thigmatropism.

All the vegetative cells of the ascocarp manifest a strong tendency to become closely appressed to one another and to the sex cells, as is shown in both early and late stages by the flattening of their surfaces of contact. The tendency of the tips of the hyphae to be pointed with the apex drawn inward toward the surface of contact (figures 7, 12 and 13) is conspicuous and significant of the physical effects of close adhesion. That the tapered form of the tips of the young hyphae of the first enveloping layer is due to adhesion with the ascogone is obvious, since the apices of other hyphae that are quite free of any contacts are well rounded, tending to a least surface configuration. The total absence of inter-hyphal spaces and general appearance of compactness of the young ascocarp are also to be noted.

The vegetative hyphae in their upward growth tend to form a uniform palisade clinging to the oogone until they meet at the apex. Since generally they do not all begin growth simultaneously, but are formed in irregular succession and are of varying ultimate heights, the final arrangement at the apex generally shows little regularity. As noted, the basal cell of the antherid contributes enveloping hyphae as well as the basal cell of the oogone and in my preparations generally, and perhaps always, produces two hyphae in addition to the antheridial branch. Text figure 2, *4*, shows a characteristic view of the enveloping hyphae that arise from the antheridial basal cell. The cell farthest to the left (text figure 2, *4a*) represents the antheridial stalk cell, the apical part of which, with the antherid, is shown in text figure 2, *5a*. The middle, somewhat shorter and younger hypha (text figure 2, *4b*) is already binucleated. The shortest hypha is the youngest and last formed of the three (text figure 2, *4c*). These hyphae all have a diameter of about 4 to 4.5 microns; the ascogone at this stage has a length of about 17 microns. The hyphae next to the antheridial stalk cell, as in text figure 2, *4b*, begins its growth immediately to the side of it, and is from the beginning in close contact with both oogone and antheridial stalk. It will therefore follow the groove whose course is the resultant of the contours of the oogone and the adjoining cell wall of the antheridial stalk. The antheridial branch, being considerably less in diameter, following the contour of the ascogone, forms a curve with a slightly lesser radius than that of the ascogone. The next branch will follow the perithecial wall. In general we may say, however, that the number of enveloping hyphae is seven or eight, and that apparently each hypha divides transversely but once, forming thus 14 or 16 cells. These cells are ultimately of approximately equal size, about 20 microns long, and 5 microns in greatest diameter (text figure 3, *17*), so that there are about sixteen somewhat similar cells in the first layer of the perithecium.

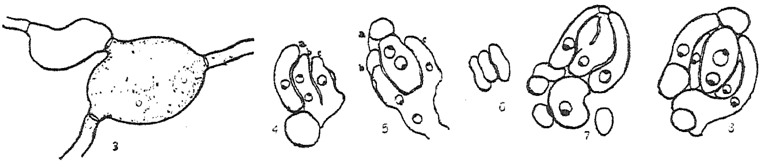

Fig. 2. *3*. Germinating conidium with only one gnarled germ-tube and two germ-tubes which resemble the mycelium. *4–6*. Three successive serial sections of a young ascocarp whose two-nucleated ascogone has not yet been completely covered by the initial envelope. *4a*, Antheridial stalk cell; *4b*, bi-nucleated enveloping hypha; *4c*, youngest of the three enveloping elements; *5a*, antherid with part of the stalk-cell; *5b* and *c*, enveloping hyphae. *7*, *8*. Two successive serial sections of a young ascocarp in which the initial envelope is complete and the hyphae which will form the second layer are pushing up between the two-nucleated ascogone and the initial envelope.

These cells constitute what we may call the initial envelope of the young ascogone. In spite of variations it seems to me that we can recognize elements and processes which are typical in the development up to this stage and that the considerable range of diversity in a series of young ascocarps is to be considered as a matter of morphotic modification.

The type process then may be conceived as consisting in the development of five enveloping hyphae arising simultaneously from the basal cell of the ascogone (text figure 2, *5* and *6*) and two from the basal cell of the antherid (text figure 2, *4*). Such a typical stage taken from living material is represented in text figures 4, *19–21*, and 5, *18*. The hyphae thus form a palisade of similar cells about the ascogone, the older previously formed antheridial stalk cell forming part of the series. These hyphae would typically all reach the antherid at the apex at the same time, and the initial envelope would consist of a palisade of similar cells about the ascogone. De Bary's (1863) figure 11, plate IX, for *Erysiphe* suggests such a type. If each of these cells now divides once in its middle and then expands laterally with the growth of the ascogone, we should have 16 truncated pyramidal cells. If there were as many as nine or ten original enveloping hyphae, the initial envelope would consist of eighteen or twenty cells.

No two perithecia are entirely alike in the arrangement and shape of their peripheral cells at maturity. The ultimate number of cells in the outer layer of the mature perithecium is between 18 and 24, so that it is clear that there is little cell division once the ascogone is covered, and probably some of the first-formed 16 cells do not divide further.

Whether the additional cells arise from further upgrowing hyphae or by division of the typical 16–18 cells is not clear. They grow in their tangential diameter with the growth of the ascogonium, the tangential expansion taking place at the expense of their radial diameters. Ultimately in the mature perithecial wall (text figure 5, *23*, *24*) they are plate-like, four-, five-, and six-sided or irregularly shaped cells. The cells are about 6 microns in radial diameter by 6 microns in tangential diameter when the three layers of the perithecium are complete; but when the ascocarp has reached maturity, they are generally 5 microns or less in thickness by 20–30 in tangential diameter. The average tangential diameters of the cells of the initial envelope are between 20 and 24 microns. The cells have increased about 12 to 15 times in volume.

The fertilized egg nucleus divides very shortly after fusion, and the two daughter nuclei separate slightly (figures 15 and 16) and come to lie in the upper part of the ascogone (figure 17).

At this stage the ascogone is not yet completely covered and the cells of the initial envelope have not yet begun to flatten. This binucleated stage of the ascogone is apparently of rather long duration, since the greatest growth and development of the perithecial cells takes place during this period. The ascogone does not increase noticeably in diameter, but elongates considererably during the binucleated stage, the elongation apparently taking place in the lower end while the nuclei remain in the upper end (figure 17). The ascogone, which at the beginning of the formation of the initial envelope measured between 8 and 10 microns in thickness, remains so up to the four-nucleated stage, but it elongates from 18 to 30 microns. The ascogone elongates with the growth of the enveloping hyphae. However, as it becomes enclosed at the upper end with its further elongation, it becomes curved. The initiation of this curvature may take place very early, as noted above. Its further development is, however, very plainly a matter of the interplay of two factors, first, its own growth in length and, second, the resistance offered by the cells of the primary envelope. It is obvious that less resistance is offered to lateral expansion with the assumption of a globular form than would be offered to further elongation into a cylindrical form. The position of the apex of the ascogone is for a time at least fixed by its adhesion to the antheridial cell. The stalk cell of the antherid, after its function is completed, apparently does not elongate further. The result is the curvature of the elongating ascogone in such a fashion that the centre of its convex surface comes to point vertically upward and thus fixes the location of the spatial center of the future ascus.

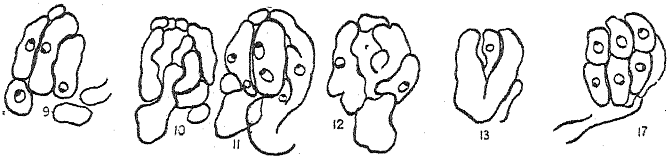

Fig. 3. *9–13.* Five successive serial sections of a young ascocarp showing the typical, irregular habit of growth of the enveloping hyphae after the initial layer is complete. *17.* External view of the initial envelope; each hypha has divided once.

Figure 20 represents an ascogone similar to the one represented in figure 22, but this figure shows it rotated 90 degrees on its vertical axis. The base of the ascogone is decidedly narrowed, and suggests that the vegetative hyphae may exert considerable pressure in this region.

This narrowing of the base of the ascogone begins to appear after the first layer of the perithecial hyphae is complete (figure 17), and from the general appearance of this region it appears as if the ascogone were wedged in on all sides. This constriction becomes more pronounced, until the base has the form of an inverted cone (figures 20, 23). However, the constriction of the base of the ascogone is not always so pronounced and often appears to be quite wanting (figures 18, 21, and 22).

When the primary envelope has completely enclosed the ascogone, a second layer of hyphae begins to develop between it and the ascogone. The hyphae that form the inner layer arise from the basal cell, alternating with those of the ascogone (figures 16 and 18), and appear to wedge their way between ascogone and primary layer, becoming, as a result, somewhat wedge-shaped at their ends. In pushing upward these hyphae force the outer layer outward and away from the ascogone (figures 13, 16 and 18), so as ultimately to form a second complete layer about the ascogone.

The antherid and its stalk cell, which in the beginning were part of the initial envelope, have become a permanent part of this layer, and are separated with it from the ascogone by the intercalated secondary layer. In figure 19 the elongated antheridial stalk cell may be seen as part of the outer wall of the perithecium, the empty antherid in this case being lifted entirely above the ascocarp. This is a common appearance. The old antherid very frequently appears as though the enveloping hyphae had forced themselves under it (figures 13, 18, and 19).

With this stage the rudiments of the cortical layer are in the main complete. The ascocarp at this stage, when the two first layers of the perithecium are complete, has an outside diameter of about 35 to 40 microns (figures 18, 20, and 21). The perithecium seems to expand more rapidly in its diameter than the ascogone grows in size, so that there is a tendency to leave vacant space between the two.

Development of the sex cells, the ascogone, and the ascus

After the mycelium has reached a certain stage of maturity, the sex cells develop. They tend to grow upward, away from the leaf surface, at angles varying around 90 degrees. They rarely stand at exactly 90 degrees to the host surface; commonly they are about 60 degrees and occasionally at 45 degrees to the substratum. I find no evidence that these cells in their growth react in any way to light or gravitational stimuli. The mildew, as stated above, is either epiphyllous or hypophyllous, and the leaves are inclined at varying angles to the sunlight. The sex cells of *Sphaerotheca* show equally varying positions, whether on one side or the other. Negative response to moisture, hygromorphosis, may be concerned in determining their general positions.

The distribution of the sex cells on the mycelium illustrates perfectly the conception that sexual reproduction is the expression of what we crudely call maturity in the life cycle of the mycelium. The sex cells are formed from hyphae about six microns in diameter, when the mycelial patches are a millimeter or more in diameter, and they appear successively as the mycelium spreads and the hyphae attain a certain maturity. At the time the sex cells appear, the hyphal cytoplasm is homogenous and only very slightly vacuolate. The assumed physiological changes of sexual maturity come to expression as a difference in staining reaction, both between antherid and oogone and between them and the vegetative hyphae.

The antheridial branch in my preparations is always in advance of the oogone in development (figures 1, 2, 3, 4, 5, and 6), or rather is always longer, for the total volume of the two cells seems to be about the same. In the stage represented by figure 5 the average dimensions of the oogones are about 7 by 15 microns, of antherids 5 by 25. The two branches adhere closely, and often it appears that the more rapidly growing antheridial branch tends to bend the oogone to one side. The preparation represented in figure 3 clearly illustrates this point. Since the oogone does not keep pace with the more rapidly elongating antheridial filament, the two bend toward the oogonial side. This may explain why the oogone and the ascogone are also so commonly inclined at an angle less than 90 degrees to the leaf surface. The study of living material shows that even the very young stages are generally at such an angle.

I am inclined to believe that the curve in the oogone, the bending over upon itself in the later stages of its development before the formation of the ascus, is initiated by this curvature of the oogone. I shall discuss this later on.

The antheridial branch is about twice the diameter of the mycelial hypha from which it arises, and appears as an elongated, stout, somewhat pointed cell, closely appressed to the oogone and growing in the same direction with it (figure 1). The single large nucleus that is at the base of the branch divides, and a wall separates the sister nuclei, which are now about one-half the size of the original nucleus, and one remains in the newly formed basal cell (figure 3), while the other migrates to the upper part of the branch where another division takes place. The resulting nuclei have about one-half the diameter of the original nucleus of the antheridial cell (figures 5, 6, 7), though the upper one is considerably smaller and migrates to the very tip of the cell where it is cut off by a wall (figures 5, 6, 7). The resulting uni-nucleated apical cell becomes the antherid. Thus three uni-nucleated cells are formed, a small, oblong, somewhat cap-like cell, the antherid (figure 7), a longer portion whose protoplasmic content is homogenous and tends to stain more densely than that of the other cells (figure 7). The antheridial stalk cell is rather stout in the middle and tends to taper at each end with the nucleus in the middle (figures 7, and 10). The basal cell is decidedly vacuolate (figure 6). The whole filament closely follows the contour of the oogone and its tip, the antherid, lies more or less on the apex of the latter (figure 5, 7, 10). Occasionally the antherid is placed a little to one side of the apex, as shown in figures 8 and 11.

The oogonial branch is generally about three times the diameter of the hypha from which it arises, and appears as a short, stout, somewhat ovoid uni-nucleated branch. Occasionally an oogonium appears slightly narrowed towards its apex, as in figure 4; but I am not certain that this is not due to the treatment by fixatives. The oogonial branch contains near its base a single large nucleus, which is about 5 microns in diameter, slightly larger than that of the nucleus of the branch destined to produce the antherid (figure 1). The oogonial nucleus divides, and a wall separates the daughter nuclei (figures 2, 3). The cross wall is marked by a slight constriction and is placed about one-third of the distance from the base of the oogonial branch to its apex (figures 2, 3, 4). The upper two-thirds of the branch becomes the oogonium, which at this stage is markedly turgid, ellipsoid, and thin-walled. The cytoplasm of the oogone at this stage may be homogeneous or very finely granular, and shows no vacuoles; but the basal cell begins to show very small vacuoles, even at this early stage, and its cytoplasm is less homogeneous (figure 6). The nucleus of the oogone is considerably larger than that of any other cells of the group, measuring about 3.5 microns. The oogonium now bulges slightly at the apex, forming a papilla. The bulging region shows a strong affinity for the red stain of the Flemming triple stain. With Unna blue it stains very deeply, appearing very dark blue even in otherwise weakly stained preparations. It seems probable that there is a gelatinization of the walls between antherid and oogone in this region. Preparations of a stage a little later show a comparatively thick cell wall in this region which stains very dark red and again suggests that the wall is gelatinous at this point.

Fertilization is accomplished by the breaking down of the adjoining walls of the antherid and the oogone, followed by the entrance of the male nucleus into the oogonium and ultimately the fusion of oogonial and antheridial nuclei. The pore is most clearly visible when the antherid and oogone are viewed from the side (figures 8, 10). The cytoplasm of the two cells is seen to be continuous, though there is no evidence that the entire contents of the antherid is emptied into the oogonium. Only the antheridial nucleus migrates into the oogonium, where it moves immediately to the female nucleus.

In figure 5 the sexual cells are complete, and fusion is about to take place. The region of fusion shows the characteristic staining reaction. In figure 8 the fusion pore is distinctly seen in section, the cytoplasm of the one cell is in contact with that of the other, and the small male nucleus, which is just within the oogonium, has apparently just entered it. In figure 9 the male and female nuclei are lying side by side, and are about to fuse. Which of these two figures represents the older stage, I am unable to say. The cells shown in figure 14 are larger, and one of the first of the enveloping hyphae is beginning to grow from the basal cell. It may therefore be considered the older. The two nuclei are now about equal in size, the antheridial nucleus having grown slightly (figure 9). Both male and female cells are in this case considerably smaller, and they may be regarded as in a slightly earlier stage than that shown in figure 14. In figure 11 the two nuclei have fused completely; the nucleus here is about 5 microns in diameter, having apparently about twice the combined volume of the two figures in figure 14. In figure 10 are represented a pair of larger sex cells, in which the sexual nuclei have already fused. The fusion nucleus here has a volume about equal to that of the volume of the two sexual nuclei represented in figure 14. Figures 12 and 9 may represent successive stages of a smaller pair of sex cells than those represented in the figures 10 and 14. Such figures merely represent variations in size of the gametic pairs. A figure like that represented in figure 12 would never in the immediately following stage look like the one represented in figure 10.

The fusion nucleus now undergoes a division resulting in two equal-sized daughter nuclei, and a rapid growth of vegetative hyphae about the two-nucleated ascogonium takes place.

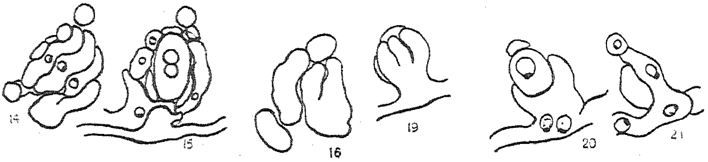

Fig. 4. *14–16.* Young ascocarp showing irregular development of the perithecial wall. In *14*, there is a slight tendency of the hyphae to form a spiral pattern. *19–21.* Successive sections of a one-nucleated ascogone with more or less uniformly developing enveloping hyphae.

The two nuclei of the ascogone during the development of the perithecium divide once so that there are four at about the time when the third layer of the perithecium is complete (figure 24). I am of the opinion that these nuclei arose by a simultaneous division of the two nuclei in the ascogone. I have never found a distinct three-nucleated ascogone but have many preparations which show four nuclei in the ascogone and many preparations which show ascocarps at about the same stage of development as the four-nucleated ones but with only two nuclei in the ascus. It is therefore very probable that the four-nucleated immediately follows the two-nucleated stage, the nuclei dividing simultaneously. Cross walls then separate the terminal and basal nuclei from the middle pair in the ascogone. There thus results a column of three cells, of which the middle one is binucleated and develops to form the ascus. The binucleated central cell, the penultimate cell, is in the region of the ascogone in which the bending takes place (figure 25), so that from the outset it bulges out much more on its convex side. It expands very rapidly and soon becomes short and pear shaped (figures 26, 27, and 29).

The two nuclei in the penultimate cell move together (figure 25) and fuse (figure 26), forming the definitive nucleus of the ascus. Figure 26 represents a young ascus showing the fusion nucleus in which the nucleoli have not yet fused. The young ascus at this stage has a diameter of about 15 to 18 microns, the diameter of the whole ascocarp being around 40 microns. After nuclear fusion the ascus continues to expand very rapidly, apparently in every direction (figures 26, 27, 28), and the nucleus enlarges with it. In the beginning the nucleus is elongated, appearing to be drawn away from its basal position (figure 27). The ascus apparently becomes very turgid to conform, in spite of the irregularities in the perithecial cells and its original shape, to a least surface configuration. At its base the young ascus tends to remain narrowed as though pinched by surrounding cells for a considerable period (figures 26, 27, and 29), and in some cases this pinched condition is never entirely lost. The ascus grows rapidly and symmetrically against the pressure of the perithecial wall. Its basal portion is the last to round out and lose its blunt-pointed shape. Many asci do not become spheres, but remain slightly dorso-ventrally flattened, appearing oval in section (figures 33, and 35).

The cell wall of the ascus is very thin up to the time the spherical shape is attained, but after this there is a gradual thickening as maturity is approached. In the stage shown in figure 30 the cell wall is shown as very much thickened.

Further growth and ripening of the perithecial envelope

The inner zone of the perithecial wall develops between the ascogone and the second layer and apparently arises largely by growth of the cells of the second layer (figure 29). That is, we now have a beginning of radial growth inwardly from the envelope toward the ascogone. In figure 22 the two elongated cells in the lower right-hand side of the figure have the appearance of having elongated radially and are about to divide. Immediately above these two cells are a short and a long cell which apparently are the result of division of a single elongated cell. Possibly the two cells below will divide similarly, and in this manner the innermost layer of perithecial cells may arise. The third layer, as noted, begins to develop at a time when the curved ascogone does not completely fill the perithecial wall. Its cells at first push into the spaces around the ascogone and show no tendency to tangential flattening. Later, when the ascus begins to swell rapidly, they are pushed back so as to form a layer of cells of fairly equal size and constant shape (figures 31, 33, and 35). On the right-hand side in figure 22 there are three cells of the inner layer which, because of their narrowness and obvious connection with the basal cell, appear to have arisen by upgrowth from it and not by ingrowth from the secondary layer. The innermost layer of cells arises both by transverse divisions of the ingrowing branches from the second layer and in lesser degree by further upgrowth from the basal cell. The ingrowing branches would typically tend to become cylindrical hyphae, but they take on such shapes as their position permits. Ultimately they are irregularly polygonal in tangential aspect and irregularly quadrilateral in radial section (figure 29). The ascocarp shown in figure 31 has almost reached its maximum size, and the cells of the outer layer are beginning to approximate their ultimate plate-like form. The inner cells are still large and isodiametric, and interhyphal spaces are present. The whole perithecium in this figure has about the number of cells commonly found when the ascocarp is mature, and probably there is no further increase in the number of the perithecial cells after this stage. With this stage the growth of the perithecium is complete, and its further modifications are those of differentiation and specialization.

After the nuclear fusion the young ascus grows very rapidly, the ultimate cell and the stalk cell of the ascogone become part of the inner layer of cells of the perithecium. These cells of the ascogone remain distinct for a time, as is shown by their different staining reaction (figures 29, 31, 34 and 35); but when the ascus expands their identity is lost and they can no longer be distinguished easily from the other cells of the inner layer.

The cells of both the outer cortical layers of the perithecium now begin to show changes in their appearance. The cell walls become slightly thickened and the contents vacuolated. I am of the opinion that after this stage they no longer divide, the ultimate number of cells between 18 and 22 being reached at this time. As the cells grow tangentially they leave no intercellular spaces between them. The hyphal cells adhere very closely and are in intimate contact throughout. They form a strong limiting layer against which the inner cells are flattened by the inflating ascus. In figure 35 the ascus has expanded considerably beyond the size shown in figures 27 and 29, and the cells of the inner layer are becoming flattened radially. Ultimately the ascus obviously develops a high turgor pressure which flattens the cells of the softer inner layer so that they become quite thin (figures 33 and 35).

These inner radially growing cells of the perithecium retain their protoplasmic contents even to a very late stage, when the spores are completely developed. Even in early stages they have a different staining reaction from that of the wall cells and doubtless they have a different function. They are large and rounded in the beginning and decrease in size with the growth of the ascus. The natural suggestion is that they are nurse cells for the ascus, as was noted by Harper (1895), and always remain thin walled.

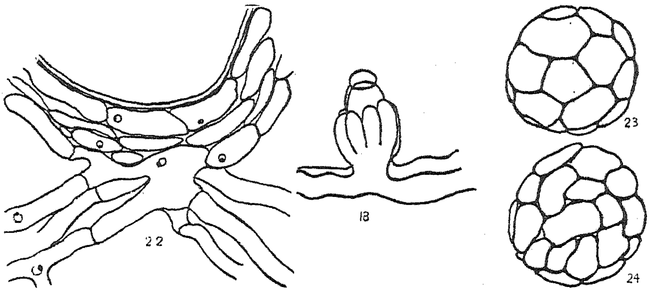

Fig. 5. *22.* Base of a mature ascocarp raised from the leaf surface by the appendages. *18.* Asocogone with palisade of enveloping hyphae growing uniformly upward. *23, 24.* Apical views of mature ascocarps showing the typical patterns of the perithecial cells.

The basal cell of the ascogone in these later stages is still clearly differentiated from the surrounding cells, and there is apparently a definite functional connection between the ascus and the stalk cell of the whole ascocarp (figure 31). It is, however, possible that after the ascocarp has reached its maximum diameter there is no further absorption from the substratum, the ascus growing at the expense of the perithecial cells—probably the inner nurse layer.

During the earlier stages, when they are still large and isodiametric, the cells immediately surrounding the ascus are regularly uni-nucleated; but later, when the ascus has taken on its illipsoid shape, these cells become bi-nucleated to tetranucleated. The cells of the two wall layers also contain one or two, rarely three nuclei in fully developed ascocarps.

The appendages begin to appear when the three layers of the perithecium are complete. They arise from the outer layer of cells in the basal region of the perithecium. They are eight to twelve in number and are long (300 to 400 microns), nucleated, tortuous, and hyphae-like. Occasionally an appendage is branched. They interweave with the vegetative mycelium, and it is often difficult to distinguish the appendages from this mycelium. When the ascocarp is mature, it is often seen lifted up above the leaf surface to a height equal to its own diameter. Apparently it is raised above the leaf surface by the appendages which are directed downwards at an angle (text figure 5, *22*). There is no evidence of any special mechanism in the appendages which serves to raise the ascocarp from the leaf surface, such as is found in *Phyllactinia*. Apparently it is due to the downward growth of the numerous appendages.

Epiplasmic inclusions

I first observed highly refractive, conspicuous granules in the ascus of *Sphaerotheca castagnei* in material fixed with Allen's modification of Bouin's fixative. These granules stain bright ultramarine blue with the triple stain. In very late stages they stain red. Merkel's fluid, Herman's fluid, picroformol, plain Bouin and Allen's Bouin give preparations in which the granules appear bright blue when the triple stain is used. With Flemming's fixing solution such granules do not generally appear, though occasionally hyaline, refractive granules resembling them in shape, number, and location may be found. It is probably because of the very widespread use of Flemming's fixative, in which the granules are scarcely if at all differentiated, that they have hitherto been overlooked in the mildews.

Unna's polychrome blue, when used with Allen's Bouin, Merkel's or plain Bouin fixative, gave varying results. The granules usually stained a deep violet, purple or reddish purple color, though sometimes they showed pale blue or greenish blue and occasionally would take no stain (figure 34) at all, even though other parts of the ascocarp showed well stained granules. While the granules frequently exhibited very distinct metachromasy with Unna blue, I have never obtained with this dye the bright red granules described by Guilliermond (1904) for the granules in the asci of *Aleuria cerea*, *Helvella sulcata*, etc.

The perithecial cell granules are very small, numerous, and purplish in color with the Unna dye, and appear long before any granules become visible in the ascus. These are quite different in appearance from those which later develop in the ascus, remaining small, very dense and staining dark blue with Unna blue even in very late stages, while those in the ascus become very large, less numerous, and not so dark in color.

No such granules appear in any of the cells at very early stages of the developing ascocarp. Only after three layers of perithecial cells are formed do they begin to appear, the first ones becoming visible in the innermost cells (figure 28). The perithecial cell granules are fairly numerous from the beginning and become several times larger and more numerous in later stages (figure 33). The epiplasmic granules do not appear until after nuclear fusion. Here again they are numerous from the beginning, becoming more numerous and larger as the ascus increases in size. The granules appear to be formed only after a cell has reached a certain stage of development. In cells that have just divided no granules are present, as for example in certain cells surrounding the penultimate cell represented in figure 28. Here certain cells of the third layer have no granules, while others have extremely minute, barely visible granules. The perithecial cell granules in the second and first layers are larger and more numerous, while the penultimate cell has none. It is difficult to ascertain from my preparations how these granules arise in the cells.

The epiplasmic granules, even in the early stages, are found each lying in a clear area in which they are eccentrically placed and increase many times in diameter as development proceeds, from particles barely visible with highest magnification to those as great as seven microns in diameter. When the ascus has reached its maximum diameter, the granules are from three to six microns in diameter and appear to fuse (figure 33). The fusion appears to be merely a physical result of their coming in contact through an increase in their diameter and perhaps through cytoplasmic movement. The largest granules appear in the ascus during the uni-nucleated stage, when certain of them may attain a diameter of ten microns. After the first division of the ascus nucleus during the two-nucleated stage, there are present numerous small epiplasmic granules varying in dimensions but below 2.5 microns or very rarely 3 microns in diameter (figure 30). Such granules vary in their staining reactions; some become red, some blue with the triple stain, though all appear to stain blue when the treatment with safranin is very brief. If these granules are similar to those in the immediately preceding uni-nucleated stages, it is difficult to understand how the abrupt change in their size takes place. Large granules occur in all the late uni-nucleated stages but the immediately following bi-nucleated stages have the small granules. Throughout the four- and eight-nucleated stages as well as in certain eight-spored stages the small epiplasmic granules persist.

In stages in which the outer perithecial cell walls are brown and the protoplasts extremely vacuolated, large irregular pale blue masses, from eight to fifteen microns in diameter with from one to four dense, dark blue, spherical centers and resembling several fused, large granules of the kind found in uninucleated asci, are present in the epiplasm. They appear to be aggregates of large granules and may arise as Bunge (1895) described by the fusion of other granules. In addition to these, many small granules like those described are also present in the epiplasm as well as in the spores (figure 35).

Similar granules are common in young hyphae. In conidiophores and conidia, as well as in the germ tubes of the latter, granules of similar appearance are also frequently present.

In still later stages large, often irregular granules, six microns in diameter, both red and blue in the triple stain, occur in the epiplasm. These are probably degeneration products and unlike any of the granules described above.

In the fusion nucleus of the ascus granules similar to those in the epiplasm occur (figure 27). I have not found them in any other nuclei of the ascocarp, the large nucleus in the ascus being the only one in which they are definitely recognizable.

In the ascus during the uni-nucleated stage, the epiplasmic granules are indiscriminately scattered in the epiplasm. There is not the slightest tendency for them to be localized at any time, either about the nucleus or in any other region of the ascus. They present no evidence of connection with or origin from the nucleus or through its agency. There are commonly, as noted, both large and small granules within the nucleus, but these are not generally in connection with the chromatin. Guilliermond's (1903) suggestion that the granules may be formed as a result of secretions from the nucleus or that they are secretion products from the chromatin finds no support from my study of *Sphaerotheca*.

Judging from their spherical form, the granules are liquid or semi-liquid substances chemically different from the surrounding epiplasm. They arise perhaps as very minute droplets secreted by the cytoplasm.

DISCUSSION

In the light of the specificity in host relations found in the mildews of P. Magnus (1898), Salmon (1904), Steiner (1908), Reed (1908), Woronichine (1914), and others and of the morphological variations which have been reported as occurring in single species, as recognized in Salmon's monograph, I am of the opinion that further study may lead to the recognition of many of the current biological races of mildews as varieties or even species. Woronichine has already reported variations in the dimensions of ascocarps, asci, spores and certain sterile hyphae of *Sphaerotheca pannosa* on the rose and of *Sphaerotheca pannosa* on the peach and on the basis of both the physiological and morphological differences proposes to recognize them as distinct varieties.

The fact that on a particular host there may be two or more asci in a form which usually has but one ascus and that the perithecium which usually consists of but three layers occasionally has four or even five layers as well as other structural variations, shows the need of further study of the species question in these fungi.

Harper (1895) describes the ascogone in *Sphaerotheca* as consisting regularly of a column of five or six cells, while Dangeard (1896) figures only three. In my own preparations I find regularly three cells in the ascogone and in only one instance a four-celled stage (figure 38) among several hundred three-celled ascogones. That such basic structures can so vary seems hardly probable, and the need of study of further forms is obvious.

Gäumann (1926) has suggested that the lack of agreement in the conclusions drawn from observations on the morphology and development of the mildews may be due to the fact that the studies were made on material from different host species.

The great similarity between the parenchyma of higher plants and the pseudoparenchyma of fungi is striking in view of the difference in the method of their formation. Parenchyma is formed by the growth and division of the cell in length, breadth and thickness. Pseudoparenchyma is formed by the growth, branching, interweaving, and adhesion of hyphal filaments.

The special relations between the cells in a parenchyma are determined largely by their method of origin, though the evidence seems to favor the view that the contact relations of the protoplasts may be dependent on the secondary development of plasmodesmen. The interrelations of the cells in the case of pseudoparenchyma are for the most part secondary and are achieved by thigmotactic responses and adhesion. Pits and presumably plasmodesmen are present and serve possibly as conductive channels through which morphotic stimuli are transmitted from cell to cell.

The problems involved in the distribution of the mycelium on the leaf of the host are doubtless analogous to those presented by the distribution of roots in the higher plants. It is hard to conceive that negative chemotactic responses involving repulsions are responsible for the generally radial direction of growth of the hyphae about a germinating spore. I have noted that the initial growth results in a generally radial arrangement of the main hyphal branches and that the typical appearance of the mycelium on an infected area of leaf is that of a radiating system of hyphal filaments. According to Nöll (1900) the radial direction of growth of secondary plagiotropic roots after the removal of an interposed barrier is due to morphaesthesia. According to this conception the main orienting factors in hyphal growth would be matters of rectipetiosis. Further observations should be made to test this and other hypotheses as to the factors which determine the growth directions of the hyphae on the leaf.

The differences in the staining reaction between the sex cells themselves and between them and the vegetative hyphae suggest physiological differences which may be chemical in nature. Whether these changes should be classed as rectipetioses is to be determined perhaps by Pfeiffer's (1925) limitations of the conception. Pfeiffer holds that the internal morphotic factors operate as specific substances which are produced by the tissues and are carried from cell to cell or through conducting channels to more distant tissues whose growth forms may be thus determined. The difference in staining reaction in the sex cells, as described above, may possibly be an indication of the formation of such specific substances.

It is evident that carpogenesis is initiated by fertilization, and it is natural to assume that the latter process involves the formation of specific substances which act as stimuli in initiating the outgrowth of the hyphae of the primary envelope. Such stimuli may be classed as carpogenic factors. The substance may be of the nature of hormozones in Gley's (1911) sense and in a morphogenetic sense may be called morphones.

The development of the perithecial wall does not generally begin before the fusion of the sexual nuclei, but I have found some cases in which the enveloping hyphae bud out before this stage. Such precocious development indicates that the stimuli to carpogenic development may arise before cell fusion occurs. The case represented in figure 13 is unusual. Fertilization does not yet seem to have taken place, but the enveloping hyphae are sprouting from the basal cells of both antherid and oogone. In figure 13 the hyphae are shown as already growing from the basal cell, yet fertilization has apparently not yet taken place. The antherid is gradually being pried away from the oogone by the hyphae which are pushing up between it and the initial envelope. That in this case an antherid is being pushed away from the oogone is possible. The antheridial filament is always more advanced in its development than any other hypha of the ascocarp, and typically occupies a position similar to that represented in figure 13. The case may be one of delayed or abortive fertilization in which perithecial development has none the less continued. It is to be noted that the oogonial nucleus in this case is unusually large and has not divided. Possibly figure 37 represents a still later stage of a similar case in which the large oogonial nucleus has still not divided, while perithecal development has gone on independently.

As noted, I have not observed the spiral pattern of the initial envelope of the ascogone regarded by De Bary as characteristic, and I am of the opinion that it is at least unusual and results only when there is a very rapid uniform development of the enveloping hyphae (text figure 4, *14*). The explanation of such a pattern is probably analogous to that generally accepted for the spiral twist in the enveloping cells about the egg of *Nitella;* that is, the combined transverse diameters of the enveloping cells are less than the circumference of the ascogone and their length considerably greater.

Several of Dangeard's (1896) figures are unlike any which I have observed. His figure 15a (p. 276, 1896) shows an oogone of two cells; figure 15d, a four-nucleated ascogone with little perithecial development; figure 15e is also unlike anything that usually occurs in my preparations. I have found occasionally some very unusual figures which in my opinion are abnormal, at least for the complete life history of *Sphaerotheca*. Some of these figures resemble certain of those of Dangeard, except that they are extremely large. Figures 36 and 37 are comparable to the four-nucleated stage represented in Dangeard's figure 14b, but in the former perithecial development has been inhibited. Figure 32 may represent a case in which the oogone has never been fertilized, yet has continued to grow. The filament (a) in figure 32 may be a degenerating antheridial filament which for some reason never came to maturity, possibly because it developed from an incompatible mycelium. The presence of two or three nuclei in the terminal cell of such a presumably unfertilized oogone is very peculiar and not easily explainable.

The stalk cell in these preparations (figures 32, 36 and 37) is in each case uni-nucleated. These naked oogones (they can hardly be called ascogones, since there is no assurance that asci ever develop from such structures) may on the other hand be looked upon as isolated oogones which have developed without the presence of antherids. The oogone in figure 13, where the male nucleus has apparently failed to enter the oogone, suggests the possibility that oogones and antherids may develop in contact and still fail to complete the process of fertilization.

The demonstration of the presence of a specially stained region of the wall of the oogone at the apex of the antherid suggests an analogy with the receptive papilla of *Pyronema*, *Albugo* (Stevens, 1899), and certain algae, such as *Vaucheria* (Oltmanns, 1895), *Oedogonium* (Klebahn, 1892). I do not find a hyaline receptive spot in the cytoplasm beneath the stained area. It is the wall of the oogone apparently which becomes differentially stained as shown in figures 6, 10, 11, and 14.

In his studies on mildews Bezssonoff (1914) is in disagreement with earlier workers on several points. According to Bezssonoff the antheridial branch of *Sphaerotheca mors uvae* does not cut off a small uni-nucleated antheridial cell as in the species of *Sphaerotheca* described by Harper (1895, 1896, 1905), Dangeard (1896), Blackman and Fraser (1905), and Winge (1911); but the antheridial branch becomes bi-nucleated, the apical nucleus migrates into the oogone, and the remaining nucleus degenerates in situ. In *Microsphaera*, Bezssonoff claims to have a stage showing the passage of the male nucleus into the oogone, though his figure 3, plate VII, does not show this very clearly. The fusion pore differs from previously described fusion pores in the mildews in being at the extreme end of the area of contact between the antherid and oogone, their walls at this point appearing to form an almost straight line.

The initiation of perithecial development in the mildews by the formation of a circle of perithecial hyphae which grow out radially from the stalk of the ascogone, and the development between these hyphae and the ascogone of further series of hyphae, parallels in principle the corresponding stages in the development of the apothecial envelopes of *Pyronema* and other Discomycetes. The subsequent transformation of these vegetative hyphae into the variously shaped plate-like cells of the perithecium, the differentiation of the outer cortical layer into dark colored, thick-walled cells and the inner layer into thin-walled cells from which the nurse layer develops, are to be regarded as expressions of the most specialized morphotic responses so far described for any ascocarp. In the formation of the layers of pseudoparenchyma of the mature perithecium, two types of development may be recognized. The initial envelope and the inner perithecial layer may be regarded as at first a simple prosoplectenchyma which is developed symphyogenously. The mature paraplectenchyma (Lindau, 1899; p. 25; Gäumann, 1926) or pseudoparenchyma results from the transformations through thigmotactic responses of the prosoplectenchyma (Lindau, Gäumann) into the compact mature tissue of the outer wall. I have never found any evidence of meristogeneous division at any stage in the development of the cleistocarp. The mature cells are variously quadrilateral, pentagonal, hexagonal or irregular in tangential section and very much flattened as a result of pressure from the growing ascus. Thigmotactic responses with radial pressure from the ascus are the dominant factors in determining their form.

The spherical ascus of *Sphaerotheca*, as compared with the club-shaped forms of the Discomycetes and the intermediate forms in *Erysiphe* and *Phyllactinia*, illustrate how pressure may modify the tendency to a least surface configuration. When in *Sphaerotheca* two asci are developed in a single perithecium they modify one another's form at their surfaces of contact so that the adjoining walls become flattened and the asci become approximately hemispherical. In cases where three asci are produced as reported by Salmon (1900), they probably assume a form analogous to that of the carpels of an orange. The more numerous the asci become, the greater must be their mutual lateral pressures and the more elongated and club-shaped is the form (see Harper's figure 40, plate XII, 1896).

The name nurse tissue is suggested for the innermost layer of the mature cleistocarp of the mildews because of its suspected connection with nutrition of the ascus, as indicated by Harper (1896 and 1905). Harper (1896) also suggests that this layer may be capable of swelling on taking in water, causing the ascocarp to burst through high turgor of these cells, in order to liberate the ascopores. The fact that this layer is soft and moist at the time of spore discharge and that the whole ascus sometimes slips out (Salmon, 1907) or is ejected forcibly (Smith, 1884) also suggests its connection with spore discharge. Possibly this layer functions during the growth of the ascus as a nurse layer and is later instrumental in bursting the cleistocarp.

The appendages in *Sphaerotheca* closely resemble in their origin the secondary mycelium probably present in most ascocarps and described by Harper in *Pyronema* (1900). The secondary mycelium in the case of the larger ascocarps doubtless functions in the nutrition of the later growth stages. For the relatively small ascocarps of the mildews, nutrition seems adequately provided through the stalk of the ascogone. De Bary

(1863), in his general description, states that secondary mycelium in the mildews is developed at an early stage. The morphological evidence seems to favor the view that the mildews are not primitive, but highly specialized in connection with their obligate parasitism.

With the acquisition of the parasitic habit and the reduction in size of the ascocarp, the secondary mycelium became nonfunctional. Obviously the appendages are to be regarded as vestigial secondary mycelium. There is no evidence that the appendages of *Sphaerotheca* ever develop haustoria. Their ends are in all cases free and undifferentiated. In forms of the Erysiphaceae in which the appendage endings are branched or otherwise modified they apparently are acquiring new functions. The highly specialized structure of the appendages of *Phyllactinia* is adapted for lifting the cleistocarp up from the leaf surface. This is, then, a case in which vestigial organs have become secondarily specialized and have acquired a very specific new function.

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Literature cited

Atkinson, G. F. 1906. The development of *Agaricus campestris*. Bot. Gaz. **42:** 241–264.

Blackman, V. H., and Fraser, Helen. 1905. Fertilization in *Sphaerotheca*. Ann. Bot. **19:** 567–569.

Bary, H. A. de. 1863. Entwicklungsgeschichte der Ascomyceten. 38 p. Leipzig.

———. 1859. Zur Kenntnis einiger Agaricinen. Bot. Zeit. **17:** 385–401.

———. 1870. *Eurotium, Erysiphe, Cicinnobolus.* Nebst Bemerkungen über die Geschlechtsorgane der Ascomyceten. Abh. d. Senck. Ges. **7:** 361–455.

———. 1884. Morphologie und Biologie der Pilze. 558 p. Leipzig.

Bauke, H. 1876. Beiträge zur Kenntnis der Pycniden. Nova Acta **38:** 443–510.

Bezssonoff, N. 1914. Quelques nouveaux faits concernant la formation du périthèce, etc. Bull. Soc. Mycol. France **30:** 279–291.

Brefeld, O. 1883. Botanische Untersuchungen über Schimmelpilze. Bd. III, 174 p. Leipzig.

Buller, A. H. R. 1905. The reactions of the fruit bodies of *Lentinus lepideus* to external stimuli. Ann. Bot. **19:** 427–438.

Buller, A. H. R. 1909. Researches on fungi. Vol. I, part II. 287 p. London.

Bunge, R. 1895. Über Sporenbildung bei Bacterien. Forschritte d. Medicin **13:** 813–826, 853–862.

Dangeard, P. A. 1897. La reproduction sexuelle des Ascomycètes. Le Botaniste **5:** 245–284.

Delitsch, H. 1926. Zur Entwicklungsgeschichte der coprophilen Ascomyceten. Inaugural Dissertation. 40 p. Leipzig.

Fayod, V. 1889. Prodrome d'une histoire naturelle des Agaricinnees. Ann. Sci. Nat. Bot. VII, **9:** 181–411.

Gaümann, Ernst. 1926. Vergleichende Morphologie der Pilze. 626 p. Jena.

Gley, E. 1911. Le néo-vitalisme et la physiologie générale. Rev. Scientifique **49:** 257–265.

Göbel, K. 1902. Morphologische und Biologische Bemerkungen. Die Verschiedene Ausbildung der Fruchtkörper von *Sterium hirsutum* Flora **90:** 471–476.

Guilliermond, A. 1903. Contribution a l'étude de l'épiplasme des Ascomycètes et recherches sur les corpuscles métachromatique des champignons. Ann. Mycol. **1:** 201–215.

————. 1904. Formation des asques et de l'épiplasme des Ascomycètes. Rev. Gen. Bot. **16:** 50–64.

Harper, R. A. 1895. Die Entwicklungsgeschichte des Peritheciums bei *Sphaerotheca castagnei*. Ber. Deutsch. Bot. Ges. **13:** 475–481.

————. 1896. Über des Verhalten der Kerne bei der Fruchtentwicklung einiger Ascomyceten. Jahrb. Wiss. Bot. **29:** 655–685.

————. 1905. Sexual reproduction and organization of the nucleus in certain mildews. Carnegie Inst. Washington Publ. **37.** 104 p.

Hartig, R. 1874. Beiträge zur Mykologie und Phytopathologie für Botaniker und Forstmänner. Wichtige Krankheiten der Waldbäume. Berlin. p. 12–24.

Hoffman, H. 1856. Die Pollinarien und Spermatien von *Agaricus*. Bot. Zeit. **14:** 137–152.

Kempton, F. E. 1919. Origin and development of the pycnidium. Bot. Gaz. **68:** 233–260.

Klebahn, H. 1892. Studien über Zygoten. II. Befruchtung von *Oedogonium boscii*. Jahrb. Wiss. Bot. **24:** 235–236.

Lindau, G. 1899. Schwendener Festschrift. (Cited by: Lindsbauer, K. 1917. C. K. Schneider's illustriertes Handwörterbuch der Botanik. Leipzig.)

Magnus, P. 1898. Der Mehlten auf *Syringia vulgaris* in Nord Amerika. Ber. Deutsch. Bot. Ges. **16:** 63–69.

Magnus, W. 1906. Die Formbildung der Hutpilze. Arch. f. Biontologie **1:** 85–161.

Maire, R. 1905. Recherches cytologiques sur quelques Ascomycètes. Ann. Mycol. **3:** 123–154.

Meyer, Arthur. 1904. Orientirende Untersuchungen über Verbreitung, Morphologie und Chemie des Volutins. Bot. Zeit. **62:** 113–152.

Müller, K. O. 1922. Untersuchungen zur Entwicklungsphysiologie des Pilzmycels. Beitr. z. allg. Bot. **2:** 276–232.

Neger, F. W. 1902. Beiträge zur Biologie der Erysipheen. Flora **90:** 221–272.

Nöll, Konrad. 1900. Über die Körperform als Ursache von formative und Orientierungsreizen. Ver. d. Natur. Ver. von. Rheinland und Westphalen **57:** 1–6.

Oltmanns, F. 1895. Über die Entwicklung der Sexualorgane bei *Vaucheria.* Flora **80:** 388–420.

Pénau, M. H. 1912. Contribution a la cytologie de quelques microorganisms. Rev. Gen. Bot. **24:** 68–95.

Pfeiffer, H. 1925. Grundlinien zur Entwicklungsmechanik der Pflanzengewebe. Abh. Theoretischen Biol. **20:** 1–99.

Reed, G. M. 1908. Infection experiments with *Erysiphe cichoracearum.* Univ. Wisconsin Bull. 3: 341–416.

Salmon, E. S. 1900. A monograph of the Erysiphaceae. Mem. Torrey Bot. Club **9:** 1–292.

————. 1904. Specialization of parasitism in the Erysiphaceae. New Phyto'o ist **3:** 104–121.

————. 1907. Notes on the hop mildew. Jour. Agr. Sci. **2:** 327–332.

Schnegg, Hans. 1915. Zur Entwicklungsgeschichte und Biologie der Pycniden, sowie der Schlingenmycelien und Hyphenknäuel. Centralbl. f. Bakteriol., Parasitenk. u. Infekt.-Krankh. 2: **43:** 326–364.

Smith, Worthington G. 1884. Diseases of field and garden crops. 133 p. London.

Steiner, J. A. 1908. Die Specialization der Alchemillenbewohnenden *Sphaerotheca humuli.* Centralbl. f. Bakteriol., Parasitenk. u. Infekt.-Krankh. Abt. 2: **21:** 677–736.

Stevens, F. L. 1899. The compound oosphere of *Albugo bliti.* Bot. Gaz. **25:** 225–245.

Tavel, F. von. 1886. Beiträge zur Entwicklungsgeschichte der Pyrenomyceten. Bot. Zeit. **44:** 872–878.

Winge, O. 1911. Encore le *Sphaerotheca castagnei.* Bull. Soc. Mycol. France **27:** 211–218.

Wolff, R. 1877. Beiträge zur Kenntnis der Schmarotzerpilze (*Erysiphe*). Theil's Landwirtsch. Jahrb. **6:** 723–757.

Woronichine, N. 1914. Quelques remarques sur les champignon du blanc de pêcher. Soc. Mycol. de France **30:** 391–401.

Woronin, M. 1869–70. *Sphaeria lemaneae, Sordaria fimiseda, Sordaria coprophila,* und *Arthrobotrys oligospora.* Ver. Senck. Ges. **7:** 325–360.

Ziegenspeck, H. von. 1926. Schleüdermechanismen von Ascomyceten. Bot. Archiv. **13–14:** 341–381.

Zopf, W. 1887. Über einen neuen Inhaltskorper in Pflanzlichen Zellen. Ber. Deutsch. Bot. Ges. **5:** 275–286.

————. 1881. Die Conidienfruchte von Fumago. Nova Acta Acad. Acad. C. Leop.-Carol. G. Nat. Cur. **40:** 257–329.

Explanation of plates

All figures were drawn with the Abbe camera lucida. Figures 1 to 25, and figures 28, 34, 32, 36, and 37 are magnified approximately × 1200; all other figures are magnified approximately × 900.

PLATE 28

Fig. 1. Male and female branches.

Fig. 2. Later stage; the gametes are cut off from the basal cells. The cytoplasm of the oogonium is more dense than that of either the basal cell or the antheridial branch.

Fig. 3. The antheridial branch appears as if it had through more rapid growth pushed the oogonium to one side.

Fig. 4. The antheridial branch has completely overtopped the oogone.

Fig. 5. The antheridial cell is cut off from its stalk.

Fig. 6. The apex of the oogone shows a small densely stained area at the point of fusion with the oogone.

Fig. 7. An enveloping hypha is growing from the oogonial basal cell before fertilization has occurred.

Fig. 8. Antheridial nucleus has entered the oogonium; the pore has not yet closed.

Fig. 9. Stage just before conjugation. The male nucleus has enlarged and is about the same diameter as the female nucleus.

Fig. 10. Fusion has taken place; the conjugation pore has not yet closed and the densely stained area at apex of the oogonium persists.

Fig. 11. Shows the persistent densely stained area and large fusion nucleus.

Fig. 12. The enveloping hyphae in an early stage.

Fig. 13. Sex cells in an advanced stage in which the male nucleus has failed to enter the oogonium.

Fig. 14. Egg nucleus has divided; the densely stained area at the apex of the ascogonium is still present.

Fig. 15. Binucleated ascogonium with several enveloping hyphae growing from both male and female basal cells.

Fig. 16. Binucleated ascogonium with persistent densely stained area at the apex. Initial enveloping hyphae have completely covered the ascogonium and the second layer of hyphae is growing between it and the initial envelope.

Fig. 17. The hyphae of the initial envelope is cut up into several cells. The ascogonium has elongated slightly.

Fig. 18. The second layer is almost complete. Empty antheridial cell which has been pried off from the ascogonium by the enveloping hyphae is at the apex of the ascocarp.

Fig. 19. Empty male cell with its stalk embedded in the initial layer of the perithecium.

Fig. 20. An ascogonium with one very small nucleus and two equal sized larger nuclei, the latter are typical.

Fig. 21. Curved binucleated ascogone. The curve is perpendicular to the focal plane.

Fig. 22. Slightly older. The third layer of perithecial cells is nearly complete.

Fig. 23. Similar to fig. 21, but the ascogone is somewhat stouter.

Fig. 24. Both ascogonial nuclei have divided. The centripetal radial growth of the hyphae of the inner layer is shown.

PLATE 29

Fig. 25. Three-celled ascogonium. Stalk cell and basal cell are in the next section. The penultimate cell shows the two nuclei about to fuse.

Fig. 26. Fusion nucleus in the young ascus. The nucleoles have not yet fused.

Fig. 27. Young ascus with several small epiplasmic granules. The fusion nucleus shows several small blue granules.

Fig. 28. Young perithecium showing large granules in the older cells, smaller granules in the second layer and very few or none in the youngest the innermost cells. No epiplasmic granules are visible in the young ascogenous cell.

Fig. 29. The inner, nurse layer, is complete. The cells are large, inclined to be quadrilateral in section.

Fig. 30. Eight-spored ascus with numerous very small epiplasmic granules.

Fig. 31. Perithecium reconstructed from two sections. The basal cell is connected with the ascus stalk cell which contains four nuclei. The nurse layer has become considerably flattened by the growing ascus.

Fig. 32. Presumably a two-celled ascogone in which fertilization has failed to take place; enveloping hyphae have failed to develop.

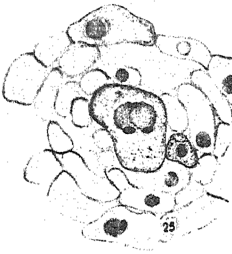
Fig. 33. Later stage than fig. 31. Large blue epiplasmic granules in the ascus, and small dense granules in the outer cortical layer.

Fig. 34. Similar to 33, but stained with Unna blue. The epiplasmic granules remain unstained while the perithecial cell granules appear deep violet in color.

Fig. 35. Eight-spored ascus with thick, apparently gelatinized, wall. Large dark blue masses containing denser spherical bodies.

Figs. 36 and 37. Stages similar to fig. 32. Fig. 36a shows what might be an undeveloped antheridial branch.

Fig. 38. A four-celled ascogone with fusion nucleus in the young ascus.



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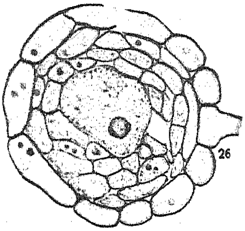

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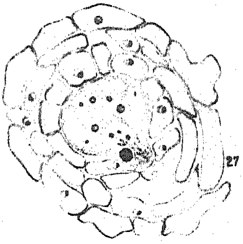

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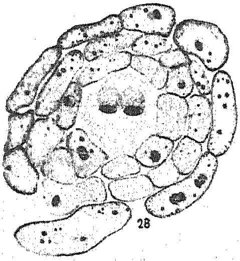

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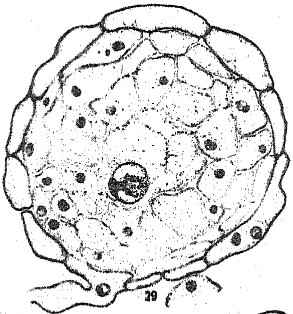

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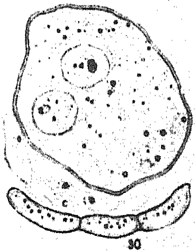

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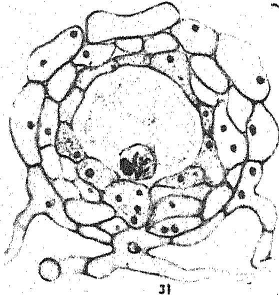

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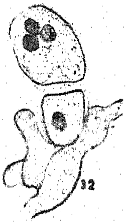

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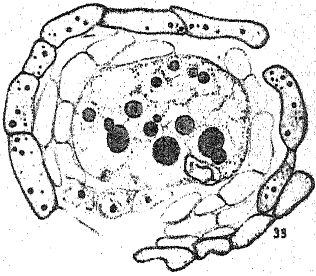

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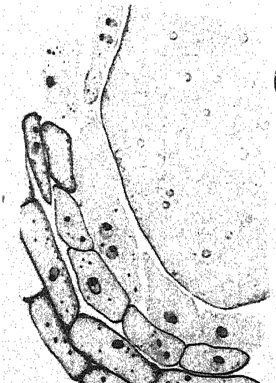

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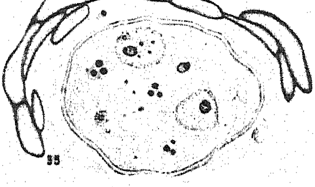

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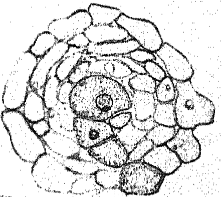

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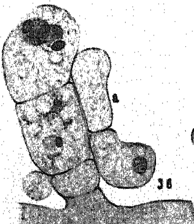

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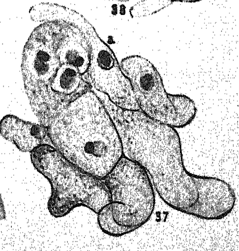

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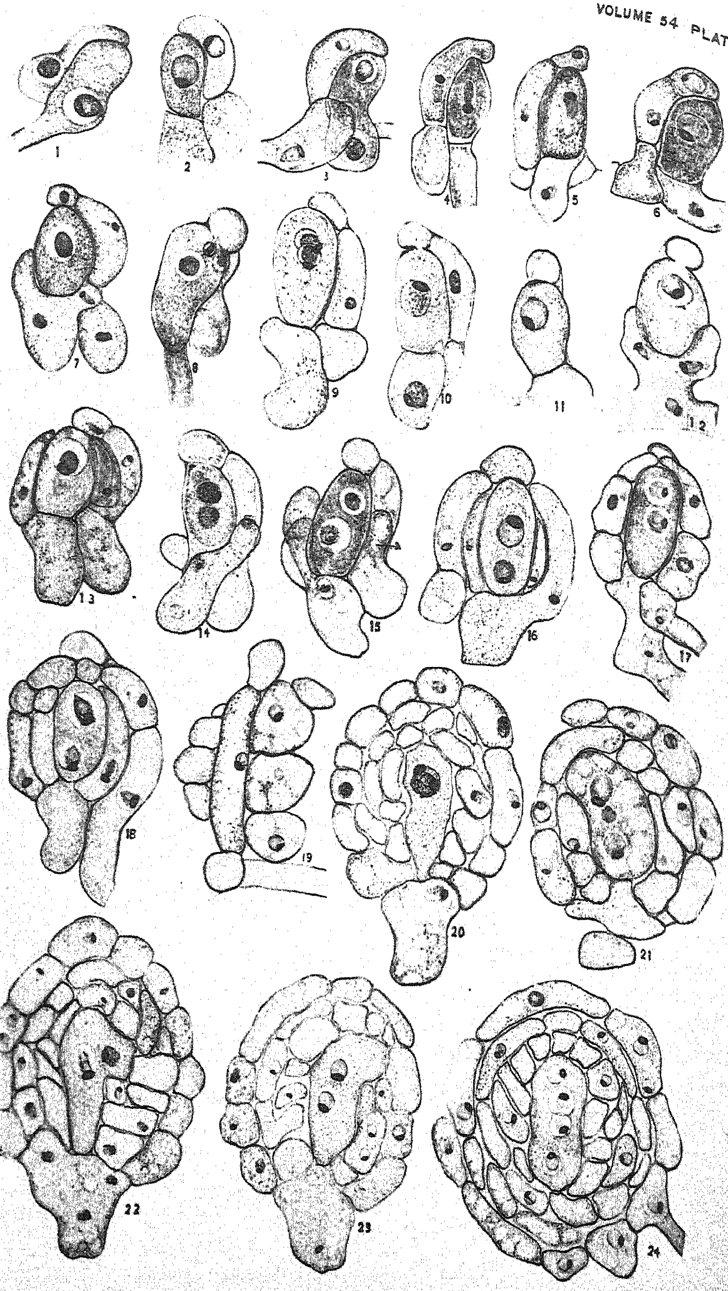

A contribution to the biophysics of Podophyllum petioles

WALTER J. HIMMEL

(WITH FIVE TEXT FIGURES AND PLATES 30, 31)

The effect upon growth of such external factors as pressure and tension has been studied by a number of workers. While it is apparent that such agencies as gravity and wind may alter the shape of stems and in some cases have altered their internal structures, yet there is a question as to whether these agencies do alter the rate of growth and the rigidity of axial organs such as stems, petioles, roots, and hypocotyls. In this connection the mechanical forces involved in the growth and curvature of such structures deserve consideration.

A knowledge of the effect of pressure and tension on growth, and the mechanical forces involved in growth, is highly important not only in explaining the behavior of plants in their tropisms but also because during normal or pathological development the cells of a multicellular plant must affect each other not only by chemical secretion but also by the mutual stresses and strains within a growing tissue. This study therefore has a direct bearing on the problem of cellular interaction during ontogeny.

Hegler (1893) investigated the influence of tension upon growth by means of attaching a thread to the tip of the shoot, passing it over a pulley, and fastening it to a weight at its free end. He found that the tensile strength of such stems increased with increased tension. In repeating these experiments Ball (1904), a student of Pfeffer, found that the breaking strength of a plant does not increase in response to a gradually increasing pull.

Pfeffer (1893) later found that the primary root of a bean seedling embedded in plaster of Paris develops a pressure of 100 to 140 grams, often sufficient to burst the cast. Later with a spring-dynamometer he determined that the pressure thus developed overcame a resistance of 352.7 grams or 19 atmospheres. He also found that resistance applied in this way caused production of mechanical tissue.

Brush (1908) found that contact has a decided strengthening effect upon the tendril of *Passiflora caerulea* and by the addition of tension a still greater strength is obtained.

In working with the woody stems of *Robinia Pseudo-Acacia*, *Rhus glabra*, *Populus tremuloides*, and *Ricinus communis*, Pennington (1910) found that there was no increase in mechanical strength under the influence of longitudinal compression. In young herbaceous stems of *Helianthus annuus*, *Vicia faba* and *Phaseolus vulgaris* he found that the development of mechanical strength was somewhat retarded by longitudinal compression caused by a heavy weight. He states further that neither light weights nor heavy weights have any appreciable effect upon the growth and strength of herbaceous stems which have already formed a cylinder of woody tissue.

The application of other pressures than that of longitudinal compression have been studied in their effect upon growth. Andrews (1922) has shown that a water pressure of 600 atmospheres reduced the growth of *Zea Mays* seedlings on the average to only a small fraction of the growth rate of the normal plants.

Pressure seems to affect certain chemical phenomena and thereby to have some influence on the energy relations of tissues. Meldolesi (1921) found that the action of pepsin and trypsin upon blood albumen was influenced by a pressure of over one atmosphere of CO_2 and N_2. The reaction was most rapid at a pressure of 5 atmospheres, less at 10 atmospheres, but more than at one atmosphere. The hydrolysis of arrow-root starch by diastase was also influenced by pressure in the same way as was the action of pepsin and trypsin.

Not many studies have been made upon the amount of work done by plants in growth. Cremieu (1923) has recently estimated the work done in growth by oats. According to his calculations 125 kgm. of oat seed planted on a hectare of ground lift during their development into mature plants 1500 kgm. of seed and 300 kgm. of straw to a height of 0.6 m.

MATERIALS AND METHOD

The so-called sterile shoots of *Podophyllum peltatum* used in this investigation have been shown by Holm (1899) to be peltate leaves. They are very suitable for investigations on the effects of pressure because of their firmness, the absence of lateral appendages, and because the region of elongation, unlike the delicate meristems of true stems, extends from near the distal end to near the middle of the petiole. In determining this region several petioles were marked at 10 mm. intervals and several at 20 mm. intervals. After several days the intervals were remeasured. Only those of the upper half of the petiole were found to have elongated. As an illustration of this elongation the following figures represent the successive intervals in mm. from the distal end of one petiole after several days growth: 20, 25, 29, 33, 21, 15, 10, 10, 10, 10, 10. A fourth advantage of this structure for such studies is that the weight can be placed directly on the top, without tying anything to the petiole.

The growing season of *Podophyllum* in any given locality continues only for a few weeks. It was found possible to secure actively growing petioles at other than the natural season both by breaking the dormancy early and by delaying development. The rhizomes bearing dormant buds were dug up in the summer and autumn and transplanted into flower pots. These pots were submerged in soil on the north side of a building and after exposure to considerable cold weather during the winter were brought into the greenhouse during the latter part of January, where the buds began to open within two weeks and in about another half week reached the stage suitable for use in the experiments. During February rhizomes were also chopped out of the frozen soil in the woods, covered with sand, and transferred to a refrigerator where they were kept at a constant temperature of about 1° C. until after the normal growing season had passed. As needed they were removed from cold storage, potted in flower pots, and placed in the greenhouse where they developed more rapidly than either the normal or the preseasonal material. Usually the buds of these plants opened in a day or two and were ready for experimentation within a week. In this way the length of the season was extended from 8 weeks to about 16 weeks.

In attempting to measure the mechanical forces involved in the growth and curvature of stems and stem-like parts of plants, and the maximum energy which the plant is capable of so expending, three groups of experiments were prosecuted. In the first group longitudinal pressure was exerted by placing on the apex of the plant a light weight (about 25 grams) and periodically increasing this weight by equal increments as long as the plant continued to raise it. The rate of elongation was recorded twice daily, and after elongation had ceased, the bending strength of the petioles was determined and also the amount of work done in raising the weight calculated. In the second group of experiments the petioles of plants were flexed back and forth in one plane alternately on either side of the vertical. This process of repeated bending, which may be given the name of flexation, was continued for several days, and as the plant elongated, the amplitude of flexation was correspondingly increased. After elongation had ceased, the bending strength of the petioles was determined in the direction of flexation and in the plane at right angles to it. In the third group of experiments plants were placed horizontal, and the energy which they are capable of expending in tropic response to gravity was measured.

ELONGATION UNDER PRESSURE

Rate of elongation

The pots containing the plants were placed in large saucers filled with wet sand on a rotating table in the greenhouse. The average diameter of each petiole, both at tip and base, was determined both before and after the experiments. Glass tubing, the diameter of which was slightly larger than that of the petioles, was split and used for encasing the latter to prevent bending. It was put in place while the plants were still small, about 7 to 10 cm. high, and was held in a vertical position by means of a burette clamp and a ring stand. A glass thistle tube, the lower end of which had been closed with sealing wax, was placed upright upon the apex of the petiole and was held in place by allowing it to slide freely within a slightly larger piece of glass tubing held in place by a second burette clamp. The thistle tube was counter-balanced by an equal weight attached to a fine wire thread running over a pulley wheel. This pulley wheel was that of a Sach's simple auxanometer which was used for determining the amount of elongation at intervals during the growing period (plate 31, fig. 1). Controls were carefully selected, one for each plant, and were similarly set up, except that no weight was added as described below for the treated plants.

TABLE I

Rates of elongation in inches per hour for five plants and their controls

PRESSURE IN GRAMS	PLANT 550 AND ITS CONTROL			PLANT 554 AND ITS CONTROL			PLANT 597 AND ITS CONTROL			PLANT 599 AND ITS CONTROL			PLANT 681 AND ITS CONTROL		
	Hrs.	Exposed plant	Control plant	Hrs.	Exposed plant	Control plant	Hrs.	Exposed plant	Control plant	Hrs.	Exposed plant	Control plant	Hrs.	Exposed plant	Control plant
25	16	.0413	.0413	16	.0337	.0550							16	.0012	.0103
50	12	.0450	.0616	12	.0466	.0858	16	.0218	.0303	16	.0116	.0313	12	.0083	.0241
75	12	.0460	.0916	12	——	——	12	.0366	.1083	12	.0666	.1158	12	.0025	.0316
100	12	.0208	.0333	12	——	.0625	12	.0575	.1083	12	.0516	.1000	12	.0008	.0325
125	12	.0166	.0460	12	——	.0583	12	.0225	.1041	12	.0591	.1040	37	.0011	.0424
150	12	.0000	.0141	12	.0058	.0316	12	.0175	.0700	12	.0175	.0566	25	.0008	.0120
175	12	.0016	.0208	12	——	.0358	12	.0008	.0608	12	.0108	.0650	70	.0009	.0079
200	12	.0000	.0150	12	.0391	.0326	12	.0191	——	12	.0250	.0775	48	.0008	.0058
225	12	.0066	.0258	36	.0016	.0305	36	.0050	.0166	36	.0130	.0194	72	.0003	.0016
250	24	.0038	.0154	84	.0027	.0112	14	.0042	.0112	12	.0050	.0166	24	.0008	.0013
275	72	.0040	.0063				24	.0041	.0100	24	.0058	.0100			
300	36	.0025	.0091				24	.0041	.0250	24	.0179	.0233			
325							24	.0012	.0083	24	.0020	.0108			
350							24	.0008	.0050	24	.0025	.0025			
375							24	.0004	.0029	24	.0008	.0054			
400							60	.0003	.0060	61	.0006	.0054			

Either twenty-five or fifty grams of mercury were poured into the thistle tube of each plant treated. The needle of the auxanometer was then set at zero, and the plants were left to grow against this pressure. After 12 hours in some experiments and 24 hours in others, an equal amount of mercury was added. If the plant succeeded in raising this weight after a like interval of time, another 25 or 50 grams of mercury were added. If, however, the petiole had not raised the weight, the mercury was not added; but the plant was left undisturbed until the auxanometer registered an increment of growth at the time of the periodic readings. Mercury was thus added until the plant could no longer raise the accumulated weight.

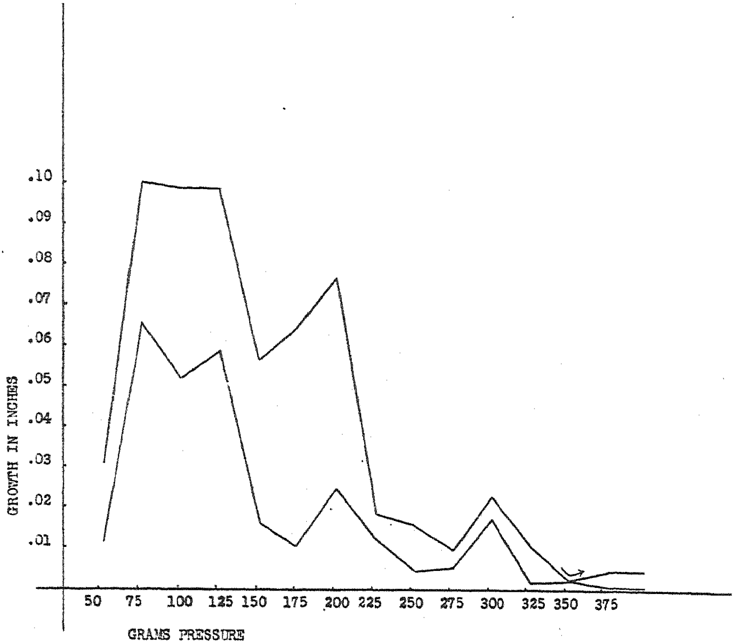

Fig. 1. Growth rates of plant No. 599 and its control represented graphically. Lower curve represents growth rate of exposed plant, upper curve rate of control plant.

The data in table 1 show that the rate of vertical elongation of the petiole decreases with increase of longitudinal pressure, but not in exact proportion. From figure 1, which represents graphically the growth rates of plant no. 599 and its control, it is seen that, in general, an acceleration of elongation of the control is accompanied by an acceleration of elongation of the exposed plant as well. Likewise, a retardation of elongation of either is accompanied by a retardation of elongation of the other, indicating that the plants are responding similarly to external conditions. It will be seen also that the first pressure of 50 grams made considerable difference in the rates of elongation. The curves are farther apart after a pressure of 75 grams is applied, and the distance between them remains large until the larger pressures of 225 grams to 350 grams are applied, when the decrease in rate of elongation of the exposed plant does not keep pace with that of the control. After 225 grams of pressure were added and until a pressure of 400 grams was reached, the rates of elongation are nearly the same, and at 350 grams of pressure the two plants are elongating at exactly the same rate per hour for a period of 24 hours. This seems to indicate that the first effect of pressure is to decrease the rate of elongation but that later the plant responds in some way to this stimulus causing an increase in the rate and that the total effect of the pressure is markedly to increase the strength of the plant and the greater the pressure the more the strength is increased.

The rates of elongation for all of the plants used were averaged for each respective pressure. The values of these rates per hour, where the 25 gram increments were used, are shown in table 2 and the corresponding graph in figure 2. As in the curves for the individual plants described above, here too we find that the effect of the increase of pressure becomes less in retarding the rate of elongation.

From the data in table 2 the amount of work done by the plants can be calculated. This can be done by substituting in the following formula: $W = 2.54 \text{ g } \Sigma \text{ (wd)}$, where W = work in ergs, 2.54 = gram-centimeter equivalent, g = gravity constant or 980.6, Σ = sum of products of w by d, w = weight added at respective intervals, and d = distance respective weights are moved. For the whole group of plants where the pressure was increased by 25 gram increments, the average total work done per plant was found to be 569, 782.76 ergs; and where the pressure was increased by 50 gram increments, the average total work done per plant was 438,367.42 ergs. There was no ap-

TABLE 2

Average growth in inches per hour for respective 25 gram increments of pressure

PRESSURE IN GRAMS	EXPOSED PLANTS	CONTROL PLANTS
25	.0218	.0276
50	.0231	.0425
75	.0274	.0736
100	.0209	.0596
125	.0173	.0644
150	.0065	.0319
175	.0037	.0257
200	.0072	.0191
225	.0029	.0113
250	.0018	.0073
275	.0025	.0061
300	.0049	.0119
325	.0017	.0095
350	.0016	.0037
375	.0006	.0041
400	.0005	.0057

parent relation between the total work done and the total weight lifted. The maximum work done by any one plant was 1,498, 175 ergs.

The greatest weight which the plant could lift under the conditions of the experiments varies from 175 grams to 500 grams, the average being 300 grams. The amount of the periodic increments does not alter the total load which the plant can lift.

Bending strength

After the plant was no longer able to raise the accumulated weight, its bending strength was determined. For this purpose the flectometer (fig. 3) was devised. This instrument consists of a dial (A) marked off in degrees, in front of which is mounted a pulley (B) with a pointer (C). A silk cord passed over the pulley and suspended two counterpoised vials (D and D′). Above vial (D) a capillary tube (E), bent in the form of a double curve, connected above through a stop-cock with a wider tube partly filled with mercury. A second silk cord attached to the same vial (D) passed up over the pulley (B) and thence horizontally for a distance of about one meter to the petiole (F). It is

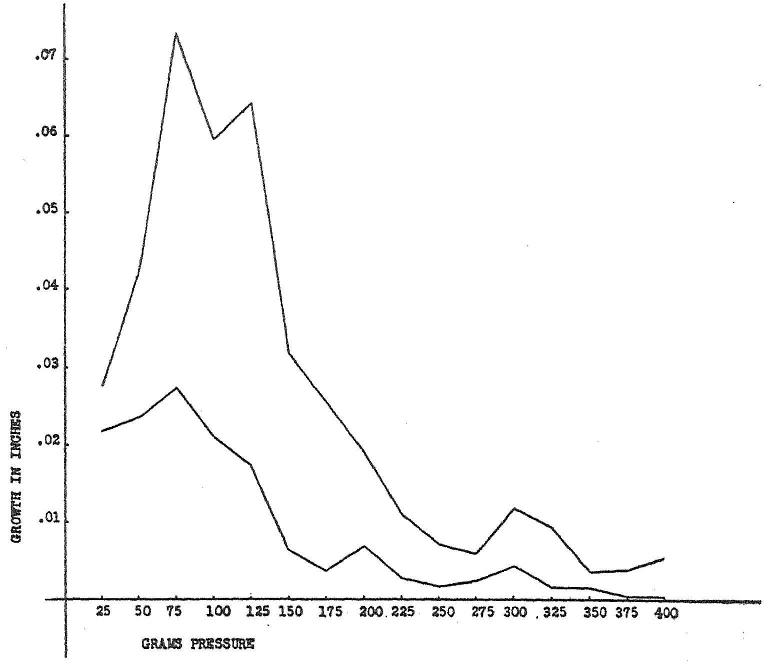

Fig. 2. Composite graph showing average growth per hour of all plants for periods of increasing pressures, based on data of table 2. Upper curve represents growth of control plants, lower curve the exposed plants.

attached to the petiole by means of a small wire hook. In order that the exposed and control plants might be tested in a comparable manner, the base of the petiole was held firm by a clamp attached at the same distance from the apex in the control as in the exposed plants, respectively. The pointer was set at zero and the stop-cock adjusted so that mercury dropped into the vial at the rate of 12 drops per minute. As the weight increased, the vial lowered, thus bending the petiole to an extent indicated by the pointer. The pointer was allowed to traverse the same angle for the exposed plant and its control. The angle chosen was a function of the length of the petiole. If the distance of the clamp from the apex was 19 cm., the angle traversed by the pointer was arbitrarily selected as 190°; if 15 cm., the angle selected was 150°; and so on. The weights of mercury required to bend the petioles to that angle were ascertained, thus measuring the bending strength.

Pennington (1910) used a scale mounted back of the tip of the inverted plant to which was attached a cord which passed over a pulley and bore a weight on its free end. He used the curvature of the stem as caused by a constant weight for measuring the resistance to bending. In our flectometer the weight is proportional to the length of the structure tested and is added very slowly, requiring all the way from twenty minutes to two hours. It furthermore seems that it is a better measure of the plant's bending strength to determine the weight required to bend it through a definite angle rather than to determine the

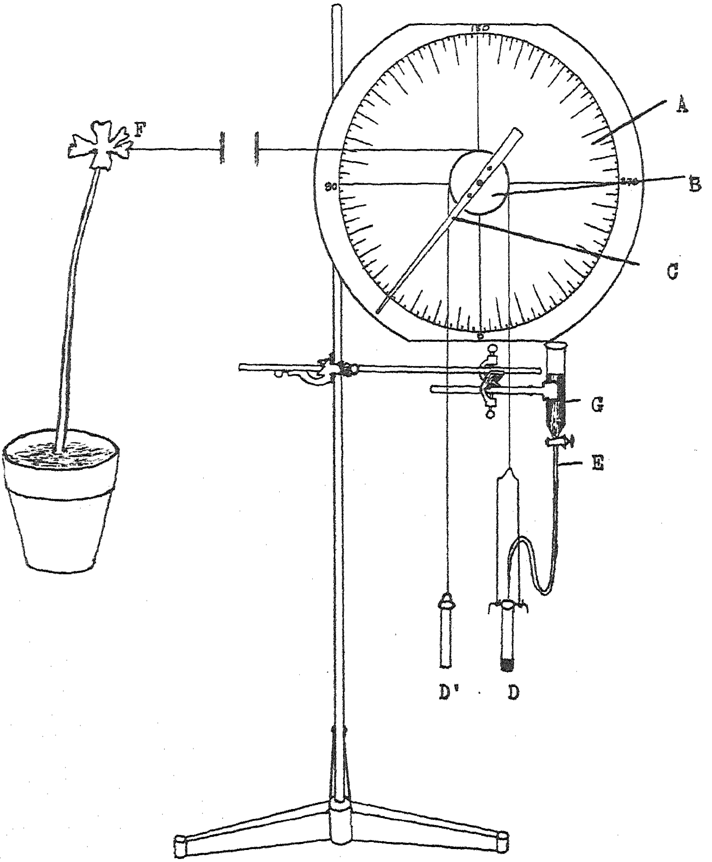

Fig. 3. Diagram of flectometer.

degree of bending by a certain weight added quickly. Plants vary greatly in their bending strength, and it is therefore unfair to apply a heavy weight to a weak plant or a light weight to a strong plant, as this may lead to considerable error in determining its real bending strength. Another advantage of the flectometer is that greater accuracy is attained by magnifying the movement with the pointer over the dial. A further feature of the flectometer is the comparatively long distance of the petiole from the pulley wheel. The very slight lowering of one end of the thread due to the bending of the petiole thus results in a negligible difference in the direction of the pull.

In table 3 are given the results of the bending strength determinations made on some plants exposed to longitudinal pressure and on their controls. In nearly every case the bending strength of the exposed petiole is greater than that of its control. In all except two cases, in which the bending strength of the control was greater than that of the exposed plant, the average diameter of the petiole was found to be larger. The average increase in strength for the plants investigated in this way was found to

TABLE 3

Bending strength of some petioles as determined by flectometer

PLANT NO.	EXPOSED PLANT				CONTROL PLANT		
	Length	Average diam.	Weight carried	Flectometer readings	Length	Average diam.	Flectometer readings
	cm.	*mm.*	*grams*	*grams*	*cm.*	*mm.*	*grams*
287	13.8	4.48	350	25.5629	17.5	4.84	30.0403
303	13.5	4.955	350	36.6566	13.5	5.10	33.3487
502	14.0	4.255	250	21.8802	14.6	3.81	16.3187
564	18.4	4.79	350	31.0081	19.9	3.585	17.3841
566	22.2	5.535	350	39.8913	23.7	5.57	31.0613
568	19.0	5.18	350	35.2213	17.0	4.44	15.7679
570	16.4	5.18	400	14.2509	25.0	4.07	14.6615
550	20.2	5.18	300	24.5395	24.5	3.45	13.8050
553	17.5	4.14	225	22.7851	22.0	4.025	15.5787
554	18.5	4.945	250	28.3726	25.0	4.0	14.2610
555	17.7	4.55	225	19.2204	28.3	5.245	29.9279
677	20.0	4.94	300	23.2325	19.5	4.28	21.6967
679	13.17	4.42	275	25.5953	22.5	4.29	32.9545
681	11.0	4.84	275	36.8603	17.0	4.18	16.9260
683	15.0	4.74	300	36.8185	14.0	5.37	37.2496
715	23.7	4.81	300	13.4910	28.4	4.78	10.2437
720	21.5	5.81	300	23.0787	16.8	5.56	22.3337

be 18 per cent. The average bending strength in terms of grams for the exposed plants was 26.9685 and for the controls it was 21.9740.

That this increase in bending strength is a permanent condition was shown by first determining it for a number of plants immediately after release from the pressure and again after the plants were left in the dark room for four days. The results were the same. If the resistance to bending had been the result only of turgidity, it seems that a decrease in turgor would follow release from the pressure and thus decrease in the bending strength.

Structural effects of longitudinal compression

The experiments described above show that longitudinal pressure during growth retards the rate of elongation and increases the bending strength of the petiole of *Podophyllum*. There seems to be, also, a certain structural modification resulting from longitudinal pressure. In this petiole there is an outer ring of bundles bounding a central pith and lying next to the inner margin of the cortex. Other bundles of the nature of leaf traces are distributed within the pith. Bordering the phloem of each bundle toward the exterior are thick-walled cells. Sections of the petiole of a control plant show very little of this mechanical tissue, whereas in sections of the petiole which grew against a final maximum pressure of 400 grams it is well developed. Furthermore, the walls of the parenchyma cells between the bundles also become thickened, and the cells are transformed into stereome. This difference is very evident in the sections of individual bundles highly magnified and shown in figures 1, 2, and 3 of plate 30. There also seems to be some difference in the organization of the xylem and in the character of the walls of the vessels.

EFFECTS OF FLEXATION

Some of the work on the effect of pressure and tension upon growth has been done by others with the view to explaining the eccentric growth of stems of Coniferous trees and the presence of "redwood." The trunks and branches of many trees have more wood on one side, and the annual rings on this thicker side are often reddish in color, resembling heartwood, the walls of the cells being much thicker and the wood much harder.

Burns (1920) exposed seedlings of pine to a bending motion to determine whether or not wind action could be the cause for the production of this mechanical tissue. He says that no "redwood" was formed nor did any eccentric growth take place as result of this bending. Koehler (1919), on the contrary, tied saplings in a circle and got red heart-wood on the inside. He attributes the formation of this "redwood" in this location to compression and not to a gravitation stimulus. Miss Gilchrist (1908), working mainly with sunflowers, reports that plants so swayed in one plane "are shorter and thicker" than control plants, that the "diameter in the plane of swaying is greater than that at right angles," that the "xylem in the plane of swaying is greater than in the transverse plane," that "a greater amount of xylem is produced than in stems of controls," that "the rigidity is greater in the diameter in the plane of swaying than in transverse diameter," and that "swaying 'in the wind' produces greater eccentricity." Hartig (1896), observing the effect of wind on trees, believed that longitudinal pressure on the cambium caused the production of "redwood." Later, however, (1901) he concluded that gravity may also act as the stimulus. Cieslar (1896) attributed the formation of "redwood" to a pressure stimulus as a result of bending young spruce trees. Ursprung (1901) maintained that it was a compression-strain stimulus resulting from the weight of the structure and the action of wind that caused the distribution of radial growth. Kny (1882) accounted for this one-sided increase in the growth of tree trunks on the basis of one-sided leafing of the tree causing one side to be heavier than the other. Growth is thus inversely proportional to the external pressure exerted upon the growing cells. Wiesner (1892) also attributed eccentric growth to unequal size and distribution of the leaves. DeVries (1876), by winding twine around stems, concluded that the presence of annual rings results from greater bark pressure at some seasons of the year than at other seasons. Krabbe (1884), however, proved that the bark pressure is never great enough to retard growth. Wortmann (1887) found that the collenchyma of the cortex of bandaged plants became greatly thickened. He attributed this to the fact that these cells could not reach their normal surface tension. Detlefsen (1882) also attributed eccentricity to bark pressure. Newcombe (1895) concluded that the formation of mechanical tissue is not always caused by mechanical forces but calls the responses self-regulatory phenomena. Keller (1896), in considering the strengthening of the fruit-bearing axis, held that it is not due to tension because of the weight of the fruit nor because of the fruit-bearing itself, but that it is the change in direction of the axis which causes the anatomical changes. Pieters (1896), on the other hand, found that lignification of cell walls and increase in cells go hand in hand with fruit development. Vöchting (1902) found no increase in mechanical tissue in weighted sunflowers, some of which had been decapitated. In Savoy cabbages, all of which were decapitated, he found only a slight increase in mechanical tissue, but this was not proportional to the weights used. By removing the flower buds, he greatly retarded the formation of mechanical tissue in these plants. Subsequent addition of weights did not cause the mechanical elements to reappear. But when he grafted another stem onto the decapitated one, the mechanical tissue again began to form, although this additional weight was much less than the weights which he fastened to the decapitated stem.

In my experiments with *Podophyllum* petioles a device called the flector was constructed for bending the petioles back and forth in one plane. This consisted of a bicycle wheel driven by a small electric motor. To the wheel was eccentrically attached a stiff wire about five feet long, which was made adjustable on the wheel so as to increase or decrease at will the amplitude of the bending. This wire was held horizontal and at any desired elevation above the table by having it pass over adjustable wheels. The tips of the petioles were fastened along the side of the wire by cord so that they would be pulled first in one direction and then in the opposite. To avoid injury to the petioles, the cord was looped about a rubber band cut from tubing, slit open, and placed about the petiole just beneath the peltate blade.

Thirty-one plants were set up in this manner when they were about three or four inches tall, the extent of bending being only about two inches. The amplitude of bending was increased from two inches to about eight inches during the period of growth which lasted for a week to ten days. As soon as the petioles reached their maximum elongation, their bending strength in two planes was determined by means of the flectometer, one plane being the same as that of the bending by the flector and

TABLE 4

Bending strength of plants which were flexed back and forth, and of controls for some of them

BENDING STRENGTH IN PLANE OF FLEXATION	BENDING STRENGTH AT RIGHT ANGLES TO PLANE OF FLEXATION	PERCENTAGE INCREASE	BENDING STRENGTH OF CONTROL PLANTS
grams	*grams*		*grams*
13.4177	14.5611	7.8	
24.4600	25.1233	2.6	
18.2003	18.9775	4.0	
16.0513	18.7273	14.0	
36.2526	38.0660	4.7	
15.9204	19.8324	19.7	
16.6287	16.9017	1.5	
28.4787	32.6488	12.7	
13.6571	14.7405	7.3	
17.6905	19.5478	9.5	
31.3711	37.1264	18.0	
14.8031	14.7245	.5	
34.1945	34.7887	1.7	
15.9371	19.9948	20.0	
11.9029	15.1808	21.0	
9.9481	10.1181	1.6	
16.4048	18.8279	12.8	
23.9100	28.9750	17.0	
14.9889	18.1944	17.0	
13.7554	15.4380	10.8	
10.0909	11.7310	14.0	
15.6587	18.4587	15.0	
8.0054	9.3630	14.5	
20.9037	28.6600	27.0	15.3924
16.8190	24.3812	31.0	21.7313
9.7771	18.2596	46.0	17.5165
30.7186	34.7196	12.0	18.3255
14.7183	16.7846	12.0	18.3094
22.0045	27.6760	20.0	20.1090
30.8175	38.7051	20.0	21.1216
19.4123	24.4924	20.0	14.6061
Average 20.4194	23.3523	14.0	18.3889

Increase over controls (based only on plants where controls were used): in plane of flexation, 12 per cent; at right angles to plane of flexation, 40 per cent.

the other at right angles to it. In table 4 is given the bending strength of these plants together with the bending strength of some of their controls. The bending strength of these plants, when determined for the same direction as the plane of flexation, was found to increase 12 per cent over that of the controls; but in the direction at right angles to this plane of flexation the increase was 40 per cent. This shows that, in *Podophyllum* at least, flexing motion results in an increase of bending strength. In all cases, except one, the bending strength at right angles to the plane of flexation was found to be greater than that in the plane of flexation. The maximum difference was 46 per cent and the average was 14 per cent.

The effect of flexation upon the bending strength of the plant is here seen to be approximately the same as that of longitudinal pressure. Here, however, the increase in the resistance to bending may be the result of the production of mechanical tissue or of a modification of form of the petiole. The length in mm. of the maximum diameters in the two planes was determined for ten plants as follows:

Same plane:	4.90	5.64	5.40	6.60	6.00	4.84	4.92	4.80	5.43	4.53
Right angles:	4.94	6.48	5.34	6.60	6.34	4.97	5.35	5.25	5.82	4.84

This gives an average maximum diameter in the same plane as flexation of 5.306 mm. and an average maximum diameter at right angles to the former plane of 5.5593 mm., showing a difference of .287 mm. This result of flexation in producing a difference in the diameter of the petiole may account for the difference in bending strength, although this evidence cannot be considered as being conclusive.

MEASUREMENT OF THE ENERGY OF GEOTROPISM

The force exerted by a petiole of *Podophyllum* in elongating vertically has been measured above. The force required to bend the petiole has also been ascertained. It now remains to be determined whether a stem or petiole in curving is capable of exerting more force than that which is just required to bend it. This can be done by finding the lifting power of such an organ during geotropic curvature.

Many workers have attributed geotropic curvature to the effects of pressure and tension upon growth. Ricome (1920), supports the theory that negative geotropism may be due to the weight of the terminal portion of the plant causing a compression below which stimulates growth and a tension above which retards it. This pressure may not be due to the weight of the tissues, but it may be an increased osmotic pressure, as suggested by DeVries (1880). He concluded that gravity produces an increased osmotically active material in the cells of the lower side. Cielsielski (1872) observed a difference of the sap on the opposite sides; the cells of the convex-becoming side contained a thin watery protoplasm, and the cells on the side becoming concave had a denser and more opaque plasma. Kohl (1894) found in the sporangiophores of *Phycomyces* that in geotropic stimulation the plasma of the concave side became much thicker and that of the convex side thin and watery. On the other hand, Hilburg (1881) found that osmotic pressure of the concave side of leaf joints and stem nodes of various plants is greater than that of the convex side. Wortmann (1889) did not think that osmotic pressure had anything to do with geotropic curvature, since he could find no difference on the two sides. He thought that the thickened plasma on the concave side thickens the cell membranes on that side, making them less elastic than those of the convex side. Copeland (1900) found no difference in osmotic pressure on the two sides of stems split lengthwise and stimulated geotropically four days. Kersten (1907), using the plasmolysis method, also was unable to find any change in the osmotic pressure on the two sides. Miss Schley (1920) found that the osmotic pressure is greater on the convex side during the geotropic response, rising during stimulation and reaching a maximum at or before visible response, and decreasing as the response nears completion.

Czapek (1902) explained the response on the basis of chemical changes affected by the geotropic stimulus. Kraus (1879–1884) observed a rise in the percentage of reducing sugars and a diminution of acidity, especially in the under surface of a shoot placed horizontal. Any chemical change leading to a change of osmotic pressure would give similar results. A further evidence that a chemical change takes place is afforded by the observations of Chapman, Cook, and Thompson (1924), who found that with a concentration of CO_2 above 40–45 per cent growth ceases and with it all responses to gravity.

Haberlandt (1900) and Němec (1902) both attributed geotropic response to the settling of bodies in the plasma in a manner similar to the otoliths of animals. Zaepffel (1921) made a detailed experimental study of geotropism in the various parts of seedlings of certain grasses and concludes that movement of the starch grains disturbs the equilibrium between starch grains and the products of their hydrolysis, giving a difference of osmotic pressure which causes unequal growth of upper and lower parts of the cell. Němec (1902), Zollikofer (1918), and others found that in certain plants statolith starch disappears when placed in the dark and with the disappearance of the statolith starch also goes the ability to respond to the stimulus of gravity. Small (1920) and Bose (1920, 1921) assumed that the particles which settle carry electrical charges thus setting up a difference in potential within the cells. This increases the permeability to ions and conductivity in the upper side of the petiole more than in the under side. It also gives greater relative turgor on the under side, greater growth and therefore curvature upwards. They have been opposed in their theory by Blackman (1921) and Snow (1921) and also by Cholodny (1923). Blackman and Snow contend that an electrical potential great enough to produce the results which Small and Bose assume could not result in this way. Cholodny admits only the assumption of Small that electrically laden particles settle to the bottom of the cell.

For my experiments an instrument was constructed which automatically dropped a small weight into a container attached to the tip of the petiole, every time it raised the distance of a millimeter or less, thus pulling it back to its original position, that is, keeping the plant continuously horizontal. A kymograph records the time when each weight is dropped. This instrument may be called a tropograph.

The plant (fig. 4) was placed horizontal; the petiole encased in split glass tubing which was clamped firmly in position. Attached by a fine wire hook inserted in a loop of braid over the end of the petiole, a silk thread suspended a glass vial (B). This vial was counterbalanced by another (B′) over pulley D. In order to make certain that the braid did not slip away from the tip of the petiole, a short piece of thread was passed back of the braid just beneath the petiole, out through the deep clefts of the leaf and tied at the outside. Thus, when the plant was in

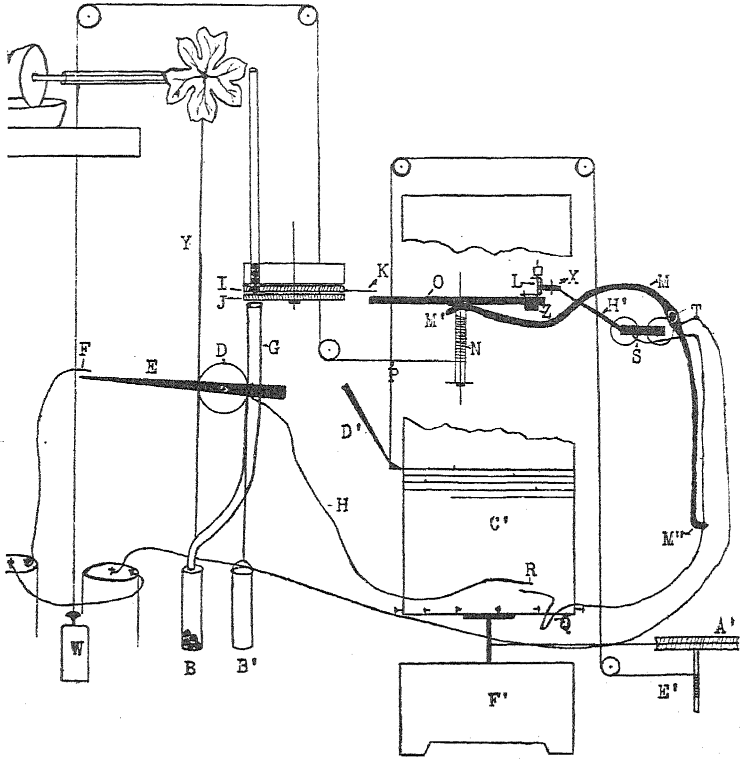

Fig. 4. Diagram of tropograph.

position, practically no weight was sustained by the petiole itself except the fine silk thread and the braid. The weight of the petiole was borne by the glass tube. Above the pointed end of arm (E) a copper wire was located connecting with four dry batteries in series. From its broader end a second wire connected with an electro-magnet (S) which operated a shot-dropping device; this magnet in turn was connected with the batteries. When the plant was placed in position, the pointed end of the arm was only 1 mm. or less from the wire (F). As the petiole rises, its movement is magnified five times at the tip of the arm. Only a very slight movement of the petiole therefore causes the circuit to close at (F) and by a mechanism, described below, a steel shot 4.5 mm. in diameter and weighing .3471 gram dropped through the tube (G) into the vial (B). In most cases the weight of this single shot was sufficient to break the circuit. After a short period the petiole rose again and once more closed the circuit, causing another shot to drop into the vial. By a continuation of this process the petiole was kept from bending upwards while for a time it continued to increase the load which it was carrying.

For the dropping device an electro-magnet was mounted so that its arm (H′) extended to a catch (X) which prevented a disc (O) from rotating. On the lower portion of the axis of this turn-table (N) was wound a cord which passed over pulleys and suspended a weight (W). Beside the disc (O) two circular brass discs (I and J) were mounted closely one above the other, the lower one fixed, and the upper one movable on the central vertical axis. Over a hole through the upper disc was attached a glass tube containing a column of shots the lower one of which rested on the lower disc. At another place in the lower disc the same distance from its center was a similar aperture beneath which was the tube (G) leading to the vial (B).

When the electro-magnet was charged, it opened the catch (X), which allowed the disc (O) pulled by the weight (W) to rotate. An arm on this disc (O) engaged a lever (K) on the upper disc (I), causing that disc to rotate a short distance, carrying the single shot in the aperture to a position over the aperture in the lower disc (J) through which it fell into tube (G) and thence to the vial. A spring drew the lever (K) back to its former position allowing another shot to fall into the hole of the upper disc. The disc (O) was prevented from rotating again by the catch (X), which was not released until the electro-magnet was again charged. This could not happen for at least one minute, due to a second break in the circuit (R). At this point was placed a kymograph bearing a row of pegs at the base of the drum. As the drum revolved the pegs moved below the wire (Q) and raised it sufficiently to make contact again. These pegs were so spaced as to make contact at one-minute intervals, thus allowing the plant to return to equilibrium after each shot was dropped. A heavy wire (M) was so mounted near the electro-magnet that a projection (Z) on the underside of the turntable (O) struck the end of the wire, thus breaking the second contact. Near the kymograph was placed a pulley (A′) turned by means of a belt connected with the shaft of the kymograph.

To the axis of the pulley was attached a fine silk thread which wrapped around it. This thread suspended a stylus (D′) which drew a spiral line on the kymograph, as it steadily raised by the thread wrapping around the pulley. When a contact was made, the arm (H′) of the electro-magnet was moved and the stylus was caused to move vertically, making a jog in the spiral line and thus indicating when the shot was dropped.

At first some difficulty was encountered when some of the petioles underwent torsion. When this occurred, the petiole would bend toward the right or left, depending on the direction of the torsion. This was overcome by mounting two small pulleys, one on either side of the tip of the petiole. A silk thread was attached to the braid over the petiole and passed over the two pulleys and downward past two other pulleys mounted close together and then attached to the vial. Thus it made no difference if the pull of the petiole were lateral or vertical; the circuit would be closed just the same, resulting in the shot being dropped into the vial.

From the kymograph records the number of shots dropped per hour was calculated and checked with the number of shots in the vial at the end of the experiment. The shots dropped in successive hours were for six plants as follows:

												Total
1:	17	6	6	14	11	9	7	1	—	—	—	71
2:	34	11	6	12	17	12	6	—	—	—	—	98
3:	16	9	9	9	11	14	14	10	8	—	—	92
4:	9	5	7	6	10	10	6	—	—	—	—	53
5:	3	2	1	5	3	4	4	4	4	4	3	37
6:	23	9	14	13	10	5	6	4	4	4	—	92

The reaction time was found to vary from 24 minutes to 88 minutes, with an average of 57 minutes. It was also found that the maximum load which the plant can lift in this manner ranges from 11.451 grams to 66.553 grams, with an average of 32.804 grams.

It is seen from these data that in nearly every case the number of shots dropped during the first hour is relatively large. There is a decrease in the number of shots dropped during the next hour, this decrease being larger in some cases and smaller in others. During the third hour the number of shots dropped may increase, or this increase may not take place until the third, fourth, or fifth hour. But in every case there is a second maximum following the first maximum of the first hour. In several cases there was a third maximum.

In figure 5 are plotted the smooth curves for the total load at the end of each hour for four of the plants. In this figure the first part of the curve is convex rising rapidly. This represents the large number of shots dropped during the first hour. During the second hour the increase in the load slows up a bit. This gives a concave curve following the first convex portion. This is followed by a convex curve again indicating the second increase in load. As the number of shots dropped per hour decreases, the curve gradually flattens out until the plant has attained its maximum pulling power. This type of curve was produced in most of the thirty experiments which were performed with the tropograph.

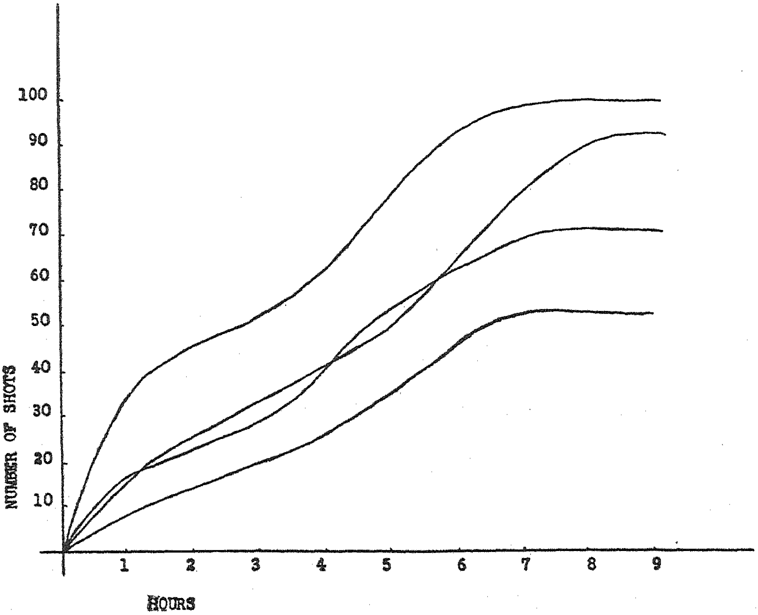

Fig. 5. Smooth curves showing number of shots in vials at successive hours for four plants.

If the weight and the glass tubing be removed from one of these petioles, the petiole immediately bends to the upper side at a visible rate (plate 31, fig. 4). The force bending the petiole to one side is often sufficient to bring the distal end in contact with the soil (plate 30, fig. 4). In one case the epidermis and cortex were ruptured because of the curvature. If it be first placed erect, the same curvature will occur, but later the terminal portion of the petiole bends upward in response to gravity.

A variation of the turgidity of the cells on the two sides of the petiole doubtless plays an important part in this curvature. That curvature of the petiole of *Podophyllum* may result from a variation of turgor was shown by removing one leaf from fertile shoots. Within less than an hour each shoot had bent over in the direction of the exposed cut surface where the leaf had been removed. The loss of water from the cut surface had decreased the turgidity of the cells on that side sufficiently to bend the distal portion of the shoot to nearly a right angle in some cases. A further indication that osmotic pressure plays an important part in such curvature of stems was obtained by taking a plant after it had curved upon release from the tropograph, peeling off the epidermis from the convex surface, and inverting the petiole in a 10 per cent salt solution. After about an hour the petiole had become straight. When rinsed and placed in fresh water, it again became curved as before. In both of these cases the curvature was brought about by contraction of the one side rather than by an elongation of the opposite side. This would seem to disprove the contention noted in the literature above that geotropic curvature is due to the extension of the lower side, and shows that it is due to a contraction of the upper side.

DISCUSSION

Pressure is known to exert a pronounced influence upon certain phases of growth and upon certain plant reactions, and it has been suggested as a possible cause of other cellular processes. Cell elongation has been shown by Newcomb (1894) to be altered by pressure. Roots encased in casts of plaster of Paris were found to have mature cells much smaller in size than normal cells and with thin walls. Likewise, cell differentiation is altered by pressure, as Pfeffer found in the Windsor bean, where spiral tracheae had developed near the tip of the root, normally developing much farther back. Jeffs (1925), in his study of root-hair formation, regarded pressure as the important factor, resulting from cellular interaction, in the production of root-hairs. He found that as the sub-epidermal cells of the root ceased elongating, thus checking vertical elongation in the epidermis, lateral evaginations of the epidermal cells due to lateral pressure developed into root-hairs. Farr (1916), in the study of cell-division of the pollen-mother-cells of certain dicotyledons, interpreted quadripartition by furrowing as being influenced by the spherical form of the mother-cells and their loose arrangement in the pollen chamber, the mother-cells thereby being free to undergo such change in volume and form as their internal constitution would favor. In most typical plant cells a cellulose wall opposes change in form and resists increase in volume; hence pressure of the cell content against the wall may account for the formation of the cell-plate.

The present study of the petiole of *Podophyllum* has determined the composite effect of pressure on all of the processes involved in growth and contributes to our knowledge of the physiology of growth by showing the influence of pressure on its rate as well as the energy relations involved both in growth and in tropic responses. It also suggests a means for the investigation of other growth movements which result from stimuli of light, wounding, etc. It gives further light on our knowledge of cellular interaction in the production of mechanical tissue as indicated by increase of strength, and aids in interpreting the responses of plants to movements effected by such agencies as wind and gravity.

It usually has been assumed that pressure decreases the rate of growth. While this is in a sense true, it does not constitute an exact description of the situation. Growth rate might be an inverse function of pressure; yet it is not necessarily proportional to it. The first effect of pressure in all of these experiments was found to be a retardation of growth, and if the weight is not further increased the normal growth rate is resumed. This is seen from the daily records where the first reading following the addition of weight is usually less than subsequent readings until addition of more weight. Thus the first effect of retardation is followed by a stimulation of growth. This is what Hegler (1893) found in the case of tension. At first it might seem that the rate of growth is inversely proportional to the weight, for the curves representing the growth of the plants and their controls gradually separate. But the fact that this does not continue and that the rate of growth of the plant exposed to pressure may exceed that of the control shows a later stimulating effect of the pressure.

The maximum energy which the petiole of *Podophyllum* with an average diameter of 4.2 mm. at its tip exerts in growth against pressure is that sufficient to sustain a weight of 550 grams. This would be equivalent to 38.75 grams per sq. mm. or a maximum of 3.75 atmospheres. The greatest pressure developed by these petioles is thus less than any of the pressures which Pfeffer found to be developed by roots of *Vicia faba*, which ranged from 5.15 to 19.35 atmospheres. The need for a pushing force by the root greater than that of a stem is obvious from the simple fact that the root must be able to force itself into the soil.

The ability of the petiole to lift a greater load after it had raised a certain weight shows that it increases in strength and points to the probability that additional mechanical tissue is produced. Further evidence of this is to be found in the average increase of 18 per cent in the bending strength of the petioles grown against pressure. These results are not in harmony with those which Pennington (1910) obtained. He found no increase in the bending strength of plants which he subjected to longitudinal pressure, nor could he find any increase of mechanical tissues when studied microscopically. This dissimilarity of results may be due to the use of different plants with apical meristem and to the different methods employed.

That pressure increases the bending strength was also shown in the flexation experiments. In flexation there is produced alternate compression and tension of the tissues on the two sides of the petiole in the plane of flexation. Here the increase in bending strength is about 26 per cent. This is comparable to the average increase resulting from longitudinal compression. Miss Gilchrist (1908), working in a similar manner with sunflowers, likewise found that flexation increased the strength of stems. One important difference is noticed, however. The sunflower stems became stronger in the plane of flexation than at right angles to it, while in *Podophyllum* the strength of the petiole at right angles to the plane of flexation was found to be the greater. In my experiments the difference in the bending strength in the two planes varied all the way from .5 per cent in favor of the plane of flexation to 46 per cent in favor of the plane at right angles to that of flexation with an average increase of 14 per cent. Miss Gilchrist also found that the diameter was greater in the plane of flexation than in the plane at right angles to it. In my experiments with *Podophyllum* it seems that the diameter of the plane at right angles to that of flexation is larger, which might, in part at least, account for the difference in bending strength in the two directions. Just how this result is produced by the action of bending, it is difficult to say. It may be that the alternate compression and tension permits less deposition of wall material in certain places.

The results of flexation are not necessarily the same as those which might follow the action of wind. Much of the work by others has been more or less confusing for the reason that what have been called wind effects have been merely bending effects. The two may be very different, for the action of wind involves increase in transpiration, which in turn would alter other internal processes that are not affected in such experiments as were performed by Burns (1920), and Gilchrist (1908). Cavara (1912), on the other hand, found that the excessive transpiration accompanying wind resulted in the shortening of the stem and tended to produce the rosette habit. In my experiments the bending did not seem to alter the average length of the petiole; the effect was purely mechanical.

That turgor plays an important part in the raising of the weights of the first group of experiments is doubtless true, but it is doubtful that it is responsible for the increase in strength as determined by the flectometer. If the weight does increase the turgidity of the petiole, then conversely, when the weight is removed, the turgidity should decrease to the normal. It is furthermore not likely that bending back and forth has a pronounced effect upon the turgidity of the tissues. If there were no structural changes produced, there would doubtless not have been such consistent differences in the bending strength in the two directions at right angles to each other as were obtained in these flexation experiments. On the other hand, the bending strength should have been approximately the same in the two directions if turgidity alone accounts for the increase. The structural basis of this increase of strength is further borne out by the microscopic sections of bundles. Ursprung and Blum (1924) account for all enlargement as a consequence of wall extension and not increased turgor pressure.

The effect of compression in producing increase in strength in the petiole of *Podophyllum* and the production of mechanical tissue supports the contentions of Hartig (1896), Ursprung (1901), and Koehler (1919) as to the formation of "redwood" in conifers, since they attribute the presence of this tissue to an increased compression stimulus on the one side of the stem.

As stated above, Ricome (1920) attributed the geotropic curvature of a stem to compression and tension stimuli. The pressure on the lower side of the horizontal plant acts as a stimulus increasing growth and the tension on the top side decreasing it. If the stem is to curve upward, according to Ricome, as a result of an increase in growth below and a decrease above, then the difference not only must represent a force equal to the weight of the stem which gives rise to the altered growth rates but also must represent an additional force equal to that necessary to bend the petiole. This theory does not coincide with Hegler's (1893) observations on the effect of tension on growth, nor with mine on the effect of pressure. Tension and pressure both seem to retard growth at first. Furthermore, the rupturing of the petiole on the side which was beneath when horizontal indicates that negative geotropism is the result of a contraction of the upper side. This is also borne out by my experiments with the fertile shoots from which one leaf had been removed and with the petiole which was placed in the salt solution.

The weight which the petiole of *Podophyllum* will lift in response to the stimulus of gravity was found to vary from 11.451 to 69.43 grams, with an average of 32.804 grams. To arrive at the total energy of the petiole in our tropograph experiments, we must consider, in addition to the weight which it is sustaining while horizontal, the force which would be required to bend the petiole at right angles. As the petiole is sustaining a maximum weight of 69.43 grams, it has remained straight and still contains potential energy equal to that necessary to bend it. Therefore the total energy of the petiole is equal to the weight sustained plus that required to bend it. From the flectometer records it is estimated that an average weight of 30 grams would be necessary to bring about the bending. Adding this to 69.43 grams would give a total of 99.43 grams as the total energy of the horizontal petiole.

That the force continues to increase for a period of time, as long as 30 hours in some cases, is significant. Schley (1920) found that the osmotic pressure continued to increase until curvature began and then decreased until curvature ceased. It is difficult to understand why this should occur. In the light of my bending-strength determinations, to the effect that the more the petiole is bent the more the force necessary to continue the bending, it would seem that in geotropic curvature, if the force responsible for it is osmotic pressure, then the latter must continue to increase until the petiole is erect and the osmotic pressures of the two sides again become equalized. The tropograph records indicate that whatever the source of the force producing geotropic curvature it increases long after the response begins. In any theory of geotropism this must be taken into account. Not only this but also the manner in which the force increases must be explained. The tropograph records have shown this increase to be periodic, first a rapid increase followed by a less rapid increase, and then a second rapid increase followed by another less rapid rise until the maximum force is developed. In some cases a third increase was found to occur.

These findings are not in accord with the observations of Zollikofer (1918) that the geotropic sensitivity is lost in the dark. If statolith starch disappears in the dark and the responsiveness to the geotropic stimulus decreases, then I am at a loss to explain the continued rise in the force developed in my experiments, for they were performed in total darkness, except for a dim red light when the readings were taken.

If we adopt Němec's theory of geotropism and assume that it is the result of the settling to the bottom of particles within the protoplasm, we can conceive of an increase in this force as taking place with the unequal settling of these particles. The heavier particles will settle first and by their hydrolysis perhaps increase the osmotic pressure below and decrease it above giving the first rise in our curve. Somewhat smaller particles will settle more slowly and while causing the force to continue to increase will probably not cause it to increase at the same rate, accounting for the first concave portion of our curve. The question now arises as to how to account for the second rise and in some cases for the third rise. If it is assumed that the particles are of two or three general sizes or that there is a synthesis of new particles, the unequal settling of them would give a periodic increase of this force. It seems that even in Small and Rea's theory (1920) of a variable permeability resulting from the differences in potential which follow a "creaming effect" that we must assume that the particles are of several sizes or newly synthesized, thus giving a periodic permeability.

These experiments were conducted in the Plant Physiological Laboratories of the State University of Iowa, and I am greatly indebted to Dr. C. H. Farr for his many helpful suggestions in the prosecution of the work.

SUMMARY

1. The maximum mechanical energy which a plant is capable of expending during growth may be measured by determining the maximum weight which the plant can lift when erect or the force exerted in lifting a weight when horizontal, plus that required to overcome its own rigidity in bending.

2. The maximum weight which a petiole of *Podophyllum* will lift when erect varies from 175 to 500 grams, with an average of 300 grams.

3. The maximum weight which a petiole of *Podophyllum* will lift when horizontal varies from 11.451 to 69.43 grams, with an average of 32.804 grams.

4. The force required to bend the petiole of *Podophyllum* varies from 9.777 to 39.891 grams, with an average of 26.16 grams. For these measurements the number of degrees of the angle of bending of each petiole was ten times the length of the petiole in centimeters.

5. Longitudinal pressure on the apex of an erect petiole results in an increase in the ability of the petiole to overcome such pressure. To lift the maximum weight so applied 10 days are required, during which the weight has been increased by 50 grams daily.

6. Lateral pressure or weight applied to a horizontal petiole of *Podophyllum* increases the ability of the petiole to curve geotropically, overcoming such pressure or weight. To lift the maximum weight so applied, from 6 to 29 hours are required during which the weight has been increased most at first, 13.537 grams per hour, with a second maximum, about 4.5 grams per hour, after about 4 hours. The rate of addition of weight falls

to 2.777 grams per hour after the first maximum and to zero after the second.

7. Pressure on the apex of a petiole of *Podophyllum* results in an average increase of 18 per cent in its rigidity.

8. Flexation—that is, the alternate bending back and forth of a stem-like axis—increases the rigidity of the structure flexed. This increase is less in the plane of flexation, being 12 per cent, than it is in the plane at right angles, in which the increase is 40 per cent.

9. The maximum work which a petiole of *Podophyllum* can do during growth is 1,489,195 ergs in 13 days.

10. In making these determinations the apparatus used consisted of: (a) Sach's auxanometer for measuring growth under longitudinal compression experiments. (b) A flector for accomplishing flexation at a constant rate over a period of several days. (c) A flectometer for measuring the rigidity of a stem, root, peduncle, hypocotyl, or petiole. (d) A tropograph for measuring the maximum force which a stem, hypocotyl, root, peduncle or petiole is capable of exerting during tropic curvature, and the rate of increase of this tropic force if curvature is prevented. The last three pieces of apparatus named were devised especially for this study.

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Literature Cited

Andrews, F. M. 1922. The effect of pressure on growth. Proc. Indiana Acad. Sci. **38:** 265–266.

Ball, O. M. 1904. Der Einfluss von Zug auf die Ausbildung von Festigungsgewebe. Jahrb. Wiss. Bot. **39:** 305–341.

Blauuw, A. H. 1915. Licht und Wachstum. Zeitschr. Bot. **7:** 465–532.

Blackman, V. H. 1921. The theory of geotropic response. New Phytol. **20:** 38–42.

Boodle, L. A. 1902. On lignification of phloem in Helianthus annuus. Ann. Bot. **16:** 180–183.

Bose, J. C. 1920, 1921. Life movements in plants. Trans. Bose Res. Inst. **3, 4:** 599–902.

Brush, N. D. 1908. The influence of contact and tension upon the tendrils of *Passiflora caerulea*. Tenth Report of Michigan Acad. Sci.

Burns, G. P. 1920. Eccentric growth and the formation of redwood in the main stem of Conifers. Vermont Exp. Sta. Bull. 219.

Cavara, T. 1912. Some investigations on the action of wind on plant growth. Exp. Sta. Record. **25:** 224–225.

Chapman, R, E., Cook, W. R. I., and Miss N. L. Thompson. 1924. The effect of CO_2 on the tropic reactions of Helianthus stems. New Phytol. **23**: 50.

Cholodny, N. 1923. Zur Frage nach der Rolle der Ionen bei geotropischen Bewegungen. Ber. d. Deutsch. Bot. Ges. **41**: 300–312.

Cielsielski, Theo. 1872. Untersuchungen über die Abwärtskrümmung der Wurzel. Cohn, Beiträge zur Biologie der Pflanzen, 2.

Cieslar, A. L. 1896. Das Rothholz der Fichte. Centralbl. Ges. Forstwesen. **22**: 149–165.

Cremieu, V. 1923. La croissance de vegetaux et les principes de la physique. Compt. Rend. Acad. Sci. Paris **176**: 263–265.

Copeland, E. B. 1900. Studies on the geotropism of stems. Bot. Gaz. **29**: 185–196.

Czapek, F. 1902. Stoffweckselprocesse in der geotropisch gereizten Wurzelspitze und in phototropische sensiblen Organen. Ber. d. Deutsch. Bot. Ges. **20**: 464–470.

Detlefsen, E. 1882. Versuch einer mechanischen Erklärung des excentrischen Dickenwachstums verholzter Aschen und Wurzeln. Arbeit. Bot. Inst. Würzburg **2**: 670–688.

De Vries, Hugo. 1876. De l'influence de la pression du liber sur la structure des couches des ligneuses annuelles. Archives Neerlandaises, 11.

————. 1880. Über die Aufrichtung des gelagerten Getreides. Landwirtschaftliche Jahrbücher **9**: 473–520.

Farr, C. H. 1916. Cytokinesis of the pollen-mother-cells of certain Dicotyledons. Memoirs New York Bot. Gard. **6**: 253–317.

Gilchrist, Maude. 1908. Effect of swaying by the wind on the formation of mechanical tissue. Report Michigan Acad. Sci. **10**: 45.

Haberlandt, G. 1900. Ueber die Perception des geotropischen Reizes. Ber. d. Deutsch. Bot. Ges. **18**: 261–272.

Hartig, T. 1896. Das Rothholz der Fichte. Forst. Nat. Wiss. Zeit. **5**: 96–109.

————. 1901. Holzuntersuchungen, Altes und Neues. Berlin. 99.

Hegler, R. 1893. Ueber den Einfluss des mechanischen Zug auf das Wachstum der Pflanze. Cohn's Beiträge zur Biol. d. Pflanzen. **6**: 383–432.

Hibbard, R. P. 1907. The influence of tension on the formation of mechanical tissue in plants. Bot. Gaz. **43**: 361–382.

Hilburg, C. 1881. Über Turgeszenz änderungen in den Zellen der Bewegungsgelenke. Untersuch. Bot. Inst. Tübingen. 1–23.

Holm, Theo. 1899, A morphological study of *Podophyllum peltatum*. Bot. Gaz. **27**: 419–433.

Jeffs, R. E. 1925. The elongation of root hairs as affected by light and temperature. Am. Jour. Bot. **12**: 577–606.

Keller, H. 1896. Ueber den Einfluss von Belastung und Lage auf die Ausbildung des Gewebes in Fruchtstielen. Inaug. Diss. Kiel.

Kersten, K. 1907. Über den Einfluss der geotropischen und heliotropischen Reizes auf den Turgordruck in den Geweben. Cohn's Beitr. Biol. Pflanzen **9**: 163–212.

Kny, L. 1882. Ueber das Dickenwachstum des Holzkörpers in seiner Abhängigkeit von äussern Einflüssen. Berlin. (Review in Bot. Centralbl. **11:** 380–384.)

Koehler, A. 1919. Eccentric growth and the production of redwood. Report, Am. Assoc. for Adv. of Sci., St. Louis, Mo.

Kohl, F. G. 1894. Mechanik der Reizkrümmungen. Marburg, Elwert **8:** 94. (Review, Beih. Bot. Centralbl. **65:** 264. 1896.)

Krabbe, G. 1884. Ueber das Wachstum des Verdickungsringes und der jungen Holzzellen in seiner Abhängigkeit von Druckwirkungen. Abhandl. Berliner Akad. (Review in Bot. Centralbl. **21:** 38–43. 1884.)

Kraus, G. P. 1879–1884. Ueber die Wasserverteilung in der Pflanze. Halle. (Reprinted from Naturforscherge-Halle: Festschr. (1879), 71 p.; Abhandl. **15:** 49–120 (1880); **15:** 229–319 (1881); **16:** 141–205 (1884).

Meldolesi, Gino. 1921. Die Wirkung von Druck auf die Geschwindigkeit der Fermenthydrolysen durch Pepsin, Trypsin, und Diastase. Biochem. Zeitschr. **115:** 85–95.

Müller, N. J. G. 1877. Beitrage zur Entwicklungsgeschichte der Baumkrone. Bot. Untersuchungen. **1:** 512–524. Heidelberg.

Nemec, B. 1902. Die Perception des Schwerkraftrezes bei den Pflanzen. Ber. d. Deutsch. Bot. Ges. **20:** 339–354.

Newcombe, F. C. 1895. The regulatory formation of mechanical tissue. Bot. Gaz. **20:** 441–448.

———. 1894. The influence of resistance on the development and life period of cells. Bot. Gaz. **19:** 149–157, 191–199, 229–236.

Pennington, L. H. 1910. Effect of longitudinal compression upon the production of mechanical tissue in stems. Bot. Gaz. **50:** 257–284.

Pfeffer, W. 1893. Druck- und Arbeitsleistung durch wachsende Pflanzen. Abhandl. König. Säch. Gesells. Wiss. **20:** 233.

———. 1903. Physiology of Plants. Vol. II. English Translation, Oxford.

Pieters, A. J. 1896. The influence of fruit-bearing on the development of mechanical tissues in some fruit-trees. Ann. Bot. **10:** 511–529.

Ricome, H. 1920. Action de la pesanteur sur les végétaux. Compt. Rend. Acad. Sci. Paris **171:** 261–263.

Schley, Eva. 1920. Geo-presentation and geo-reaction. Bot. Gaz. **70:** 69–81.

Small, J. A. 1920. A theory of geotropism; with some experiments on the chemical reversal of geotropic response in stem and root. New Phytol. **19:** 50–63.

——— **and Rea, M. W.** 1920. Preliminary notes on additional evidence for the hydrion differentiation theory of geotropism. New Phytol. **19:** 208, 209–211.

Small, J. A. 1921. The hydrion differentiation theory of geotropism. New Phytol. **20:** 73–81.

Snow, R. 1921. The hydrion theory of geotropism. New Phytol. **20:** 247–248.

Ursprung, A. 1901. Beitrag zur Erklärung des excentrischen Dickenwachstum. Ber. d. Deutsch. Bot. Ges. **19:** 313–326.

Ursprung, A., and Blum, G. 1924. Eine Methode zur Messung des Wand- und Turgordruckes der Zellen nebst Anwendungen. Jahr. f. Wiss. Bot. **63:** 1–111.

Vöchting, H. 1902. Zur experimentellen Anatomie. Nachricht. Kgl. Gesells. Wiss. Gottingen Math.-Phys. Cl. **38:** 278. (Review in Bot. Centralbl. **90:** 433–434.)

Wortmann, J. 1887. Einige weitere Versuche über die Reizbewegungen vielzelliger Organe. Ber. d. Deutsch. Bot. Ges. **5:** 459.

————. 1889. Beitrage zur Physiologie des Wachstums. Bot. Zeit. **47:** 229–304.

Wiesner, J. 1892. Untersuchungen über dem Einfluss der Lage auf die Gestalt der Pflanzenorgane. Sitzungsber. Wiener Akad. 101.

Zaepffel, Edgar. 1921. L'amidon et le géotroposme. Compt. Rend. Acad. Sci. Paris **173:** 442–445.

Zollikofer, Clara. 1918. Über das geotropische Verhalten entstärkter Keimstengel und den Abbau der Stärke in Gramineen-Koleoptilen. Beitr. Allg. Bot. **1:** 399–448.

Explanation of plates

PLATE 30

Fig. 1. Single bundle of plant grown against pressure.

Fig. 2. Single bundle of control plant.

Fig. 3. Another bundle from same plant as in fig. 1.

Fig. 4. Petiole as bent immediately upon release from tropograph and removal of glass tubing.

PLATE 31

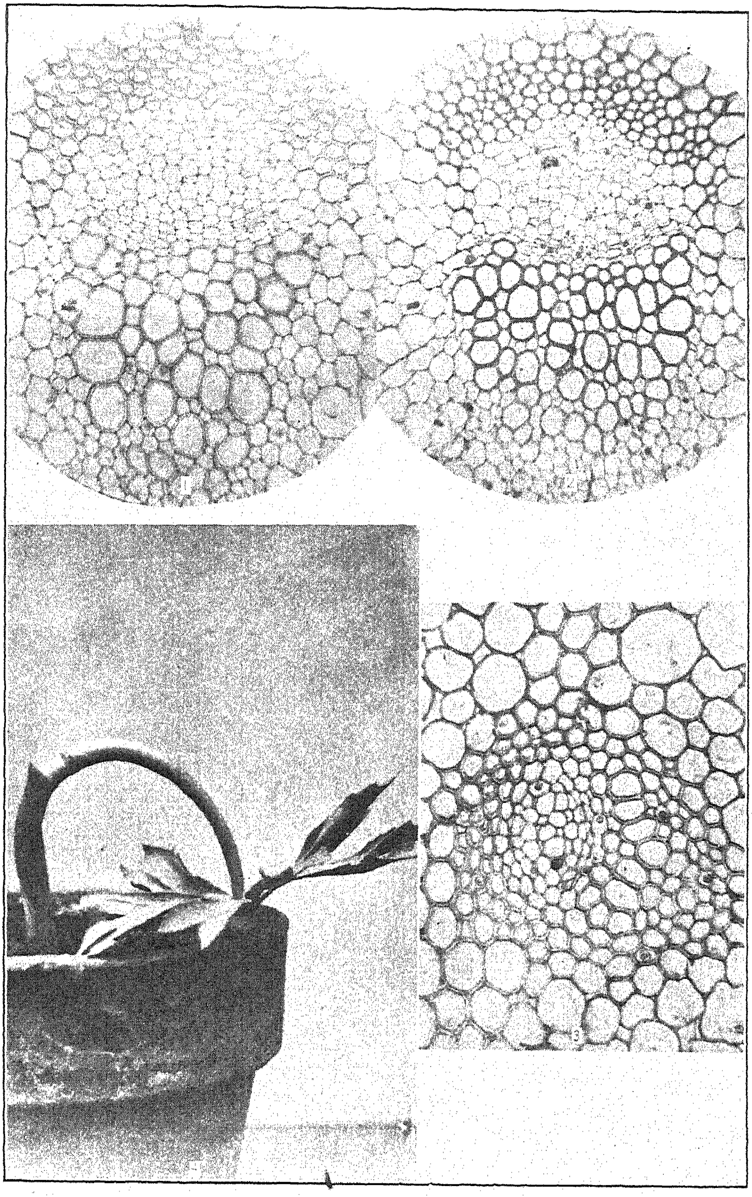
Fig. 1. Plant shown growing against pressure.

Fig. 2. Same petiole as of plate 30, fig. 4, several days later.

Fig. 3. Another petiole just taken from tropograph and before removing glass tubing.

Fig. 4. Same as in fig. 3 immediately after release from the glass tubing.

Fig. 5. Same petiole two days later.



PODOPHYLLUM PELTATUM

INDEX TO AMERICAN BOTANICAL LITERATURE
1921–1927

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Abbott, E. V. *Scolecobasidium*, a new genus of soil fungi. Mycologia **19**: 29–31. *f. 1* + *pl. 4.* 1 Ja 1927.

Aldaba, V. C. The structure and development of the cell wall in plants. I. Bast fibers of *Boehmeria* and *Linum*. Am. Jour. Bot. **14**: 16–24. *pl. 3–5.* 29 Ja 1927.

Alexander, E. J. *Helianthus tuberosus*. Addisonia 11: 57–58. *pl. 381.* "D 1926" 5 Ja 1927.
Native of central North America (?).

Andrews, A. L. *Hymenostylium longopulvinatum*. Bryologist **29**: 69–70. "N" 28 D 1926.

Archibald, R. G. Black arm disease of cotton with special reference to the existence of the casual organism *B. malvacearum* within the seed. Soil Sci. **23**: 5–10. *pl. 1.* Ja 1927.

Atwood, A. C. Peat; a contribution towards a bibliography of the American literature through 1925. U. S. Dept. Agr. Library Bibliog. Contr. 12: 1–95. S 1926.

Bailey, D. L., and Greaney, F. J. Field experiments on the control of stem rust by sulphur dust. Sci. Agr. **7**: 153–156. Ja 1927.

Bain, H. F. Cranberry disease investigations on the Pacific coast. U. S. Dept. Agr. Bull. 1434: 1–29. N 1926.

Ball, C. R. Shrubby willows of Indiana. D 1924. (In Deam, C. C. Shrubs of Indiana. Indiana Dept. Conservation Publ. 44: 35–66. *pl. 7–21.*)

Banker, H. J. Notes on Florida fungi. Mycologia **19**: 39–42. 1 Ja 1927.

Bartram, E. B. *Ptychomitrium serratum* Schimper, in western Texas. Bryologist **29**: 71. "N" 28 D 1926.

Bartram, E. B. A short list of Panama mosses. Bryologist **29**: 67–68. "N" 28 D 1926.

Becker, W. Beiträge zur violenflora Argentiniens und Chiles. Repert. Spec. Nov. Reg. Veg. **23**: 222–227. 10 D 1926.

Belling, J., and Blakeslee, A. F. The distribution of chromosomes in tetraploid Daturas. Am. Nat. **58**: 60–70. *f. 1–4.* Ja–F 1924.

Berry, E. W. An early Eocene florule from central Texas. U. S. Geol. Surv. Prof. Paper 132e: 87–92. *pl. 23.* 1924.

Berry, E. W. The Middle and Upper Eocene floras of southeastern North America. U. S. Geol.. Surv. Prof. Paper 92: i–v, 1–206. *pl. 1–64.* 10 Ap 1924.

Berry, E. W. The Mississippi Gulf in the Middle and Upper Eocene. Sci. Mo. **19**: 30–42. *f. 1–7.* Jl 1924.

Blain, W. L. Comparative morphology of dothideaceous and kindred stromata. Mycologia **19**: 1–20. *pl. 1–3.* 1 Ja 1927.

Blake, S. F. *Sericocarpus bifoliatus*, an invalid name. Rhodora **28**: 209–210. "N" 20 D 1926.

Blakeslee, A. F., and Belling, J. Chromosomal chimeras in the jimson weed. Science II, **60**: 19–20. 4 Jl 1924.

Blanco, R. A mutation in the chestnut. Jour. Hered. **17**: 403. *f. 1.* "N 1926." 15 Ja 1927.

Bogayong, J. R. Root disease on lanzones. Philipp. Agr. Rev. **19**: 259–261. O 1926.

Boyd, O. C. The relative efficiency of some copper dusts and sprays in the control of potato diseases and insect pests. N. Y. (Cornell) Agr. Exp. Sta. Bull. 451: 1–68. *f. 1–8.* Jl 1926.

Boynton, K. R. *Torenia Fournieri.* Addisonia **11**: 49–50. *pl. 377.* "D 1926" 5 Ja 1927.
Native of Cochin-China.

Boynton, K. R. *Tricyrtis hirta.* Addisonia **11**: 53–54. *pl. 379.* "D 1926" 5 Ja 1927.
Native of Japan.

Britton, N. L. *Ipomoea quinquefolia.* Addisonia **11**: 63. *pl. 384.* "D 1926" 5 Ja 1927.
Native of tropical America.

Brotherus, V. F. Musci. Insulae-Paschalis. 1921. (in Skottsberg, C. Natural history of Juan Fernandez and Easter Island **2**: 241–246. *pl. 21–23.*)

Brotherus, V. F. Musci (laubmoose). Denkr. Akad. Wissenschaft. Wien. Math-Naturw. **83**: 251–358. 18 O 1923.

Brotherus, V. F. Musci nonnulli chilenses a C. Skottsberg anno 1917 lectae. Med. Goteborgs Bot. Trad. **1**: 189–195. 3 D 1924.

Brotherus, V. F. The Musci of the Juan Fernandez Islands. 1921. (in Skottsberg, C. Natural history of Juan Fernandez and Easter Island **2**: 409–448. *pl. 26, 27.*)

Brown, N. A. A stem-end and center rot of tomato caused by various unrelated organisms. Jour. Agr. Res. **33**: 1009–1024. *f. 1–5.* 1 D 1926.

Bulger, R. O. Black stem rust and the common barberry in South Dakota. So. Dakota Ext. Serv. Circ. 240: 1–23. *f. 1–13.* Je 1926.

Bush, B. F. A new *Viburnum.* Am. Midl. Nat. **9**: 192–194. Jl 1924.
V. Ashei.

Cannon, W. A. Physiological features of roots, with especial reference to the relation of roots to aeration of the soil. Carnegie Inst. Wash. Publ. 368: i–iii, 1–168. *f. 1–21.* Au 1925.
With a chapter on the "Difference between nitrogen and helium as inert gases in anaerobic experiments on plants."

Cartledge, J. L. "Wild-flower preservation" for mosses. Bryologist **29**: 68–69. *illust.* "N" 28 D 1926.

Chamberlain, E. B. William Henry Pearson. Bryologist **27:** 12–14. *port.* Ja 1924.
Born 22 Jl 1849. Died 19 Ap 1923.

Clute, W. N. The meaning of plant names. XXIX. Polemoniaceae and Hydrophyllaceae. XXX. The borageworts. Am. Bot. **33:** 10–14; 55–60. Ja, Ap 1927.

Clute, W. N. A new frost flower. Am. Bot. **33:** 1–2. *illust.* Ja 1927.
Verbesina virginica.

Cockerell, T. D. A. The genetics of the evening primrose and mice. Nature **118:** 914–915. 25 D 1926.

Cockerell, T. D. A. Japan in 1923. Sci. Mo. **20:** 405–415. Ap 1925.

Cook, M. T. Epiphytic orchids, a serious pest on citrus trees. Jour. Dept. Agr. Porto Rico $\mathbf{10}^2$: 7–10. *f. 1–8.* Ap 1926.

Cook, M. T. *Helminthosporium* leaf spot of sugar cane in Porto Rico (preliminary paper). A method in micro-technique. A bacterial wilt of cosmos (preliminary paper). A bacterial wilt of eggplant (preliminary paper). Jour. Dept. Agr. Porto Rico $\mathbf{8}^4$: 1–16. *illust.* O 1924.

Cook, M. T. The status of plant pathology in Porto Rico. Jour. Dept. Agr. Porto Rico $\mathbf{7}^3$: 1–14. *f. 1–3.* Jl 1923.

Cook, O. F. Methaphanic variations in rose sepals. Jour. Hered. **17:** 413–426. *f. 10–15.* "N 1926" 15 Ja 1927.

Cooper, C. S. A short ramble in the Pyrenees. Bryologist **29:** 65–67. "N" 28 D 1926.

Danforth, S. T. An ecological study of Cartagena Lagoon, Porto Rico, with special reference to the birds. Jour. Dept. Agr. Porto Rico **10:** 1–136. *f. 1–45.* Ja 1926.
Flora pp. 11–18.

Darrow, G. M. Long stemmed strawberries. Jour. Hered. 17: 404. "N 1926" 15 Ja 1927.

Davenport, C. B., and Ritzman, E. G. Some wool characters and their inheritance. New Hampshire Agr. Exp. Sta. Tech. Bull. 31: 1–58. *f. 1–3.* Jl 1926.

Davis, D. E., and Beach, J. R. A study of the relative value of certain root crops and salmon oil as sources of vitamine A for poultry. California Agr. Exp. Sta. Bull. 412: 1–15. N 1926.

Dietz, S. M. The alternate hosts of crown rust, *Puccinia coronata* Corda. Jour. Agr. Res. **33**: 953–970. *f. 1–4.* 15 N 1926.

Dinsmore, J. E. A Jerusalem plant wonder. Am. Bot. **33**: 26–27. Ja 1927.

Cypress tree growing in fork of a China tree.

Dodge, C. W. Lichens of the Gaspé Peninsula, Quebec. Rhodora **28**: 157–161. 20 S; 205–207. "O" 6 N; 225–232 "N" 20 D 1926.

Doolittle, S. P., and Walker, M. N. Control of cucumber mosaic by eradication of wild host plants. U. S. Dept. Agr. Bull. 1461: 1–15. *pl. 1–3.* N 1926.

Dye, H. W., and Newhall, A. G. The control of bacterial blight of celery by spraying and dusting. N. Y. (Cornell) Agr. Exp. Sta. Bull. 429: 1–30. *f. 1–10.* Je 1924.

East, E. M., and Mangelsdorf, A. J. Studies on self-sterility VII. Heredity and selective pollen-tube growth. Genetics **11**: 466–481. *f. 1.* "S 1926" 24 Ja 1927.

Faris, J. A. Some serious sugar-cane diseases not known to occur in Cuba. Trop. Pl. Res. Found. Bull. 4: 1–22. *f. 1–10.* 6 D 1926.

Farr, C. H. The formation of root hairs in water. Proc. Iowa Acad. Sci. **32**: 157–165. "1925" 1926.

Farwell, O. A. Botanical gleanings in Michigan. Am. Midl. Nat. **8**: 263–280. N 1923.

Feirer, W. A. Studies on some obligate thermophilic bacteria from soil. Soil Sci. **23**: 47–56. Ja 1927.

Several species described as new.

Fisher, G. C. Alpine wild flowers of Arctic Lapland. Nat. Hist. **24**: 659–664. *illust.* 1924.

Fred, E. B., Whiting, A. L., and Hastings, E. G. Root nodule bacteria of Leguminosae. Wisconsin Agr. Exp. Sta. Res. Bull. 72: 1–43. *f. 1–6.* N 1926.

Fuller, A. M. The rose family in Wisconsin. Yearbook Public Mus. Milwaukee **3**: 146–156. *f. 82, 83.* "1923" 29 Ap 1925.

Gates, R. R., and Cook, W. R. I. Virescence in *Delphinium*. New Phytologist **24**: 172–179. *pl. 4.* 12 Au 1925.

Gilman, J. C. A partial list of the parasitic Ascomycetes of Iowa. Proc. Iowa Acad. Sci. **32**: 225–264. "1925" 1926.

Goldring, W. The Upper Devonian forest of seed ferns in eastern New York. N. Y. State Mus. Bull. 251: 50–92. *pl. 1–11.* 1924.

Gordon, A., and Lipman, C. B. Further suggestions for the application of the Lipman-Gordon method of tree injection. Science II, **64**: 602. 17 D 1926.

Goulden, C. H. A genetic and cytological study of dwarfing in wheat and oats. Minnesota Agr. Exp. Sta. Tech. Bull. 33: 1–37. *f. 1–4* + *pl. 1–3.* Ja 1926.

Hagelstein, R. Mycetozoa from Porto Rico. Mycologia **19**: 35–37. 1 Ja 1927.

Hanson, H. C. A study of the vegetation of northeastern Arizona. Univ. Nebraska Stud. **24**: 85–175. *f. 1–16*+ *pl. 1–9.* Jl 1924.

Harland, S. C., and Haigh, J. C. Counted grain pollinations in *Mirabilis jalapa* L. Am. Nat. **61**: 95–96. Ja-F 1927.

Harshberger, J. W. The third international phytogeographic excursion. Ecology **5**: 287–289. Jl 1924.

Hay, T. The mulleins. Am. Bot. **33**: 19–21. Ja 1927.

Heath, F. M, High-bush cranberry again. Am. Bot. **33**: 14–17. Ja 1927.

Henrard, J. T. *Bromus mandonianus* Henr. sp. nov. aus Bolivien. Repert. Spec. Nov. Reg. Veg. **23**: 177. 10 D 1926.

Henrard, J. T. *Panicum excavatum* spec. nov. aus Paraguay. Repert. Spec. Nov. Reg. Veg. **23**: 179–180. 10 D 1926.

Henrard, J. T., and Parodi, L. R. *Stipa Bonariensis* nov. spec. from Argentina. Repert. Spec. Nov. Reg. Veg. **23**: 178. 10 D 1926.

Henry, A. W. Flax rust and its control. Minnesota Agr. Exp. Sta. Tech. Bull. 36: 1–20. *pl. 1, 2.* Mr 1926.

Herter, W. Un nuevo helecho del Uruguay. Darwiniana **1**: 159–161. 1924.

Gymnogramma felipponei.

Hill, A. W. comp. Index kewensis. Suppl. 6. 1–222. Oxonii, 1926.

Hoffman, C. A. An abortive anther of *Lilium formosum*. Proc. Indiana Acad. Sci. **32**: 167–170. *f. 1–7.* "1925" 1926.

Hofmann, J. V. Natural regeneration of Douglas fir in the Pacific northwest. U. S. Dept. Agr. Bull. 1200: 1–63. *f. 1–6 + pl. 1–20.* Ap 1924.

Hollick, A. Records of glaciation in the New York Botanical Garden. Jour. N. Y. Bot. Gard. **27**: 269–278. *f. 1–7.* D 1926.

Holm, T. *Boehmeria cylindrica* (L.) Sw.—a morphological study. Am. Jour. Sci. V, **13**: 115–122. *f. 1–5.* F 1927.

Holman, R. M., and Robbins, W. W. A textbook of general botany for colleges and universities. i–vii, 1–590. *f. 1–374* N. Y., Wiley, 1924.

Hoskins, J. H. Structure of Pennsylvanian plants from Illinois. I. Bot. Gaz. **82**: 427–437. *pl. 23, 24.* 30 D 1926.

Howlett, F. S. The nitrogen and carbohydrate composition of the developing flowers and young fruits of the apple. N. Y. (Cornell) Agr. Exp. Sta. Memoir 99: 1–79. *f. 1–20.* Je 1926.

Hultén, E. *Hierochloe pauciflora* R. Br. Pflanzenareale **1**^{2}: 34. *pl. 20.* 1926.

Inman, O. L. Plant physiology. Science II, **64:** 649. 31 D 1926.

Irwin, M. Certain effects of salts on the penetration of brilliant cresyl blue into *Nitella.* Jour. Gen. Physiol. **10:** 425–436. 20 Ja 1927.

Irwin, M. The penetration of dyes as influences by hydrogen-ion concentration. Jour. Gen. Physiol. **5:** 727–740. *f. 1–4.* 20 Jl 1923.

Jaques, H. E. A tree census of Mt. Pleasant, Iowa. Proc. Iowa Acad. Sci. **32:** 201–203. "1925" 1926.

Jepson, W. L. Manual of the flowering plants of California. 1–1238. *f. 1–1023.* Berkeley, Calif., Assoc. Stud. Stores, 1923–1925.

Johnson, A. M. The bitternut hickory, *Carya cordiformis*, in northern Minnesota. Am. Jour. Bot. **14:** 49–51. *f. 1 + pl. 7–9.* 29 Ja 1927.

Johnson, A. M. Opening of the evening primrose. Am. Bot. **33:** 17–19. Ja 1927.

Johnson, A. M. The status of *Saxifraga Nuttallii.* Am. Jour. Bot. **14:** 38–43. *f. 1, 2.* 29 Ja 1927.
Genus *Cascadia*, described as new.

Johnson, E. L. Effects of x-rays upon growth, development, and oxidizing enzymes of *Helianthus annuus.* Bot. Gaz. **82:** 373–402. *f. 1–11.* 30 D 1926.

Jones, E. N. *Ceratophyllum demersum* in west Okoboji Lake. Proc. Iowa Acad. Sci. **32:** 181–188. *f. 1.* "1925" 1926.

Jones, L. R., Johnson, J., and Dickson, J. G. Wisconsin studies upon the relation of soil temperature to plant disease. Wisconsin Agr. Exp. Sta. Res. Bull. 71: 1–144. *f. 1–59.* N 1926.

Kearney, T. H., and Harrison, G. J. Length of cotton fiber from bolls at different heights on the plant. Jour. Agr. Res. **28:** 563–565. *f. 1.* 10 My 1924.

Keitt, G. W., and Jones, L. K. Studies of the epidemiology and control of apple scab. Wisconsin Agr. Exp. Sta. Res. Bull. 73: 1–104. *f. 1–8 + pl. 1–6.* D 1926.

Kiesselbach, T. A., and Petersen, N. F. The segregation of carbohydrates in crosses between waxy and starchy types in Maize. Genetics **11**: 407–422. *f. 1.* "S 1926" 24 Ja 1927.

Killip, E. P. New plants mainly from western South America. Jour. Washington Acad. Sci. **16**: 565–573. 18 D 1926.

In *Anthurium, Anthericum, Brodiaea, Zephyranthes, Boerhaavia, Escallonia, Weinmannia, Geranium, Hypseocharis, Saurauja,* and *Valeriana.*

Knowlton, C. H. Two additions to the flora of Massachusetts. Rhodora **28**: 232. "N" 20 D 1926.

Carex Michauxiana and *Amelanchier intermedia.*

Knowlton, F. H. Flora of the Animas formation. U. S. Geol. Surv. Prof. Paper 134: 71–117. *pl. 5–19.* 1924.

Knowlton, F. H. Fossil plants from the Tertiary lake beds of south-central Colorado. U. S. Geol. Surv. Prof. Paper 131G: 183–197. *pl. 41–44.* 30 Mr 1923.

Knowlton, F. H. Revision of the flora of the Green River formation with descriptions of new species. U. S. Geol. Surv. Prof. Paper 131F: 133–176. *pl. 36–40.* 30 Mr 1923.

Kühn, F. Estudio fisiografico de las Sierras de Tucumán 1–114. *f. 1–25.* Buenos Aires, Univ. Nac. Tucuman, 1924.

Kükenthal, G. Cyperaceae novae vel criticae imprimis antillanae. Repert. Spec. Nov. Reg. Veg. **23**: 183–222. 10 D 1926.

Kunkel, L. O. Studies on aster yellows. Am. Jour. Bot. **13**: 646–705. *f. 1–4 + pl. 40–44.* "D 1926" 15 Ja 1927.

Lauritzen, J. I. The relation of black rot to the storage of carrots. Jour. Agr. Res. **33**: 1025–1041. *f. 1–4.* 1 D 1926.

Lauritzen, J. I. A strain of yellow Jersey sweet potato resistant to surface rot (*Fusarium oxysporum* W. & C.). Jour. Agr. Res. **33**: 1091–1094. 1 D 1926.

Lindstrom, E. W. Genetic correlations between fruit size and color in the tomato. Proc. Iowa Acad. Sci. **32**: 179–180. "1925" 1926.

Link, G. K. K., and Bailey, A. A. Fusaria causing bulb rot of onions. Jour. Agr. Res. **33**: 929–952. *f. 1–8.* 15 N 1926.

Link, G. K. K., Jones, P. M., and Taliaferro, W. H. Possible etiological role of *Plasmodiophora tabaci* in tobacco mosaic. Bot. Gaz. **82**: 403–414. 30 D 1926.

Lockhead, A. G. The longevity of legume bacteria on inoculated alfalfa seed. Sci. Agr. **7**: 179–184. *f. 1.* Ja 1927.

Lowe, R. L. A second trip to Mount Katahdin, Maine. Bryologist **29**: 70. "N" 28 D 1926.

Lownes, A. E. *Triphora trianthophora.* Addisonia **11**: 61–62. *pl. 383.* "D 1926" 5 Ja 1927.
Native of eastern North America.

MacBride, T. H. Myxomycetal misdemeanors. Mycologia **19**: 32–34. 1 Ja 1927.

McIndoo, N. E. Senses of the cotton boll weevil—an attempt to explain how plants attract insects by smell. Jour. Agr. Res. **33**: 1095–1142. *f. 1–16.* 15 D 1926.

McNamara, H. C., Hubbard, J. W., and Beckett, R. E. Growth and development of cotton plants at Greenville, Texas. U. S. Dept. Agr. Circ. 401: 1–18. Ja 1927.

McRostie, G. P., Hamilton, R. I., and Lundblad, N. An interesting instance of root penetration. Sci. Agr. **7**: 157. Ja 1927.

Magoon, C. A., and Culpepper, C. W. The relation of seasonal factors to quality in sweet corn. Jour. Agr. Res. **33**: 1043–1072. *f. 1–12.* 1 D 1926.

Mangelsdorf, P. C., and Jones, D. F. The expression of Mendelian factors in the gametophyte of Maize. Genetics **11**: 423–455. *f. 1–4.* "S 1926" 24 Ja 1927.

Mansfield, W. J. Squibbs' atlas of the official drugs. 1–486. *illust.* N. Y., Squibbs, [c1919].

Martin, G. W. Notes on Iowa fungi,—1924. Proc. Iowa Acad. Sci. **32**: 219–223. *f. 1, 2.* "1925" 1926.

Martin, G. W. Some Amanitas from eastern Iowa. Proc. Iowa Acad. Sci. **32**: 205–213. *pl. 1–3.* "1925" 1926.

Martin, J. H., and Leighty, C. E. Emmer and Spelt. U. S. Dept. Agr. Farmers Bull. 1429: 1–13. *f. 1–7.* Jl 1924.

Meinzer, O. E. Plants as indicators of ground water. Jour. Washington Acad. Sci. **16**: 553–564. 18 D 1926.

Melchers, L. E. Economic plant diseases common in Kansas, and their control. Kansas Agr. Exp. Sta. Circ. 129: 1–23. O 1926.

Murrill, W. A. *Amanita solitaria.* Mycologia **19**: 38–39. 1 Ja 1927.

Nannfeldt, J. A. Revision des Verwndlschaft-Skreises von *Centella asiatica* (L.) Urb. Svensk. Bot. Tidsk. **18**^{3}: 397–426. *pl. 6,* 7. 1924.

Needham, J. G. Curtis Gates Lloyd. Science II, **64**: 569–570.10 D 1926.

Born 17 Jl 1859. Died 11 N 1926.

Newton, M., and Johnson, T. Greenhouse experiments on the relative susceptibility of spring wheat varieties to seven physiologic forms of wheat stem rust. Sci. Agr. **7**: 161–165. Ja 1927.

Newton, M., and Johnson, T. Physiologic forms of wheat stem rust in western Canada. Sci. Agr. **7**: 158–161. Ja 1927.

Nolla, J. A. B. The anthracnoses of citrus fruits, mango and avocado. Jour. Dept. Agr. Porto Rico **10**^{2}: 25–63. *pl. 1–6.* Ap 1926.

Nylander, A. O. The orchids of northern Maine. Maine Nat. **1**: 22–24. *illust.* 25 Ap 1921.

Ocfemia, G. O., and Roldan, E. F. *Phytophthora* blight of citrus. Am. Jour. Bot. **14**: 1–15. *f. 1–4 + pl. 1–2.* 29 Ja 1927.

Ohga, I. A comparison of the life activity of century-old and recently harvested Indian lotus fruits. Am. Jour. Bot. **13:** 760–765. "D 1926" 15 Ja 1927.

Ohga, I. A double maximum in the rate of absorption of water by Indian lotus seeds. Am. Jour. Bot. **13:** 766–772. *f. 1.* "D 1926" 15 Ja 1927.

Ohga, I. The germination of century-old and recently harvested Indian lotus fruits, with special reference to the effect of oxygen supply. Am. Jour. Bot. **13:** 754–759. "D 1926" 15 Ja 1927.

Olney, A. J. Temperature and respiration of ripening bananas. Bot. Gaz. **82:** 415–426. *f. 1.* 30 D 1926.

Osterhout, W. J. V. Exosmosis in relation to injury and permeability. Jour. Gen. Physiol. **5:** 709–725. *f. 1–4.* 20 Jl 1923.

Pammel, L. H. Our native plants. Proc. Iowa Acad. Sci. **32:** 115–121. "1925" 1926.

Pammel, L. H. Some notes on the flora of Forest and Florence counties, Wisconsin, and Iron county, Michigan. Proc. Iowa Acad. Sci. **32:** 99–114. *f. 2–5.* "1925" 1926.

Pammel, L. H., and King, C. M. Germination of some pines, and other trees. Proc. Iowa Acad. Sci. **32:** 123–132. *f. 1–15.* "1925" 1926.

Parker, R. L. The collection and utilization of pollen by the honeybee. N. Y. (Cornell) Agr. Exp. Sta. Memoir 98: 1–55. *f. 1–16.* Je 1926.

Peattie, D. C. Preparation of a local flora. Am. Bot. **33:** 5–9. Ja 1927.

Popp, H. W. A physiological study of the effect of light of various ranges of wave length on the growth of plants. Am. Jour. Bot. **13:** 706–736. *f. 1–8 + pl. 45–46.* "D 1926" 15 Ja 1927.

Rands, R. D. Snails as predisposing agents of sugar cane "root disease" in Louisiana. Jour. Agr. Res. **28:** 969–970. 31 My 1924.

Reed, G. M. Further evidence of physiologic races of oat smuts. Mycologia **19**: 21–28. 1 Ja 1927.

Reeves, R. G. Chromosome studies of *Zea mays* L. Proc. Iowa Acad. Sci. **32**: 171–176. *pl. 1.* "1925" 1926.

Richmond, T. E. Legume inoculation as influenced by stock and scion. Bot. Gaz. **82**: 438–442. *f. 1, 2.* 30 D 1926.

Ricker, P. L. Preserving the wild flowers. Nat. Mag. **9**: 97–100. [*6 col. pl.*] F 1927.

Riker, A. J. Cytological studies of crowngall tissue. Am. Jour. Bot. **14**: 25–37. *f. 1–5 + pl. 6.* 29 Ja 1927.

Riley, L. A. M. Conrributions to the flora of Sinaloa. V. Kew Bull. Misc. Inf. **1924**: 206–222. 1924.

Riley, L. A. M. Further notes on *Ouratea*. Kew Bull. Misc. Inf. **1924**: 363–365. 1924.

Roberts, E. A., and Shaw, M. F. The ecology of the plants native to Dutchess County, New York. i–iv. 1–21. 1924.

Roberts, E. N. Wyoming forage plants and their chemical composition; studies no. 7. Wyoming Agr. Exp. Sta. Bull. 146: 35–90. Je 1926.

Robertson, C. Flowers and insects. XXIV. Ecology **8**: 113–132. 29 Ja 1927.

Rogers, C. F., Durrell, L. W., and Daniels, L. B. Three important perennial weeds of Colorado. Colorado Agr. Exp. Sta. Bull. 313: 1–15. *f. 1–6.* Au 1926.

Rose, D. H. Diseases of strawberries on the market. U. S. Dept. Agr. Circ. 402: 1–8. *f. 1.* D 1926.

Rosen, H. R. Efforts to determine the means by which the cotton-wilt fungus, *Fusarium vasinfectum*, induces wilting. Jour. Agr. Res. **33**: 1143–1162. *f. 1–3.* 15 D 1926.

Safford, W. E. The potato of romance and of reality. Smithsonian Rept. **1925**: 509–532. *pl. 1–12.* 1926.

Sande-Bakhuyzen, H. L. van de. Growth and growth formulas in plants. Science II, **64**: 653–654. 31 D 1926.

Sando, C. E. The isolation and identification of quercetin from apple peels. Jour. Agr. Res. **28:** 1243–1245. 21 Je 1924.

Saunders, C. F. Flowers of midday. Am. Bot. **33:** 3–5. Ja 1927.

Mesembryanthemum edule, M. nodiflorum and *M. crystallinum.*

Schaffner, J. H. Principles of plant taxonomy. III. Ohio Jour. Sci. **26:** 294–311. *f. 1, 2.* N 1926.

Schmidt, O. C. Index algarum marinarum. Hedwigia **65:** 11–27. 1924.

Schultz, E. S. Why potatoes run out. U. S. Dept. Agr. Farmers Bull. 1436: 1–20. *f. 1–14.* N 1924.

Seil, H. A. Composition of *Nectandra coto* Rusby nov. sp. A preliminary report. Jour. Am. Pharm. Assoc. **11:** 904–906. N 1922.

Serrano, F. B., and Marquez, S. L. The red-rot disease of sugar cane and its control. Philipp. Agr. **19:** 263–265. O 1926.

Shreve, F. The vegetation of a coastal mountain range. Ecology **8:** 27–44. *f. 1–6.* 29 Ja 1927.

Santa Lucia mountains in California.

Shull, G. H. Crossing over in the third linkage group in *Oenothera.* Proc. Natl. Acad. Sci. **13:** 21–24. 15 Ja 1927.

Skottsberg, C. Bemerkungen zu einigen *Chloraea* und *Asarca* arten. Meddel. Goteborgs Bot. Trad. **1:** 211–224. *f. 1–6.* 1924.

Small, J. K. *Adenoropium Berlandieri.* Addisonia **11:** 55–56. *pl. 380.* "D 1926" 5 Ja 1927.

Native of Texas and Mexico.

Small, J. K. *Desmothamnus lucidus.* Addisonia **11:** 51–52. *pl. 378.* "D 1926" 5 Ja 1927.

Native of southeastern North America.

Smith, H. H. European botanical gardens. Yearbook Public Mus. Milwaukee **4:** 149–186. *f. 150–190.* "1924" 9 O 1926.

Southwick, E. B. *Aubrietia deltoidea.* Addisonia **11**: 59. *pl. 382.* "D 1926" 5 Ja 1927.

Native of the Levant.

Spegazzini, C. Interesante Umbelacea bonaerense. Comm. Mus. Nac. Hist. Nat. Buenos Aires **2**: 79–86. 12 Ja 1924.

Spegazzini, C. Nuevo metado de esterilizacion y nuevos substratos de cultivos. Physis **7**: 131–133. 14 Jl 1923.

Standley, P. C. New plants from Central America. VI. Jour. Washington Acad. Sci. **17**: 7–16. 3 Ja 1927.

In *Parmentiera*, *Lacistema*, *Heisteria*, *Hydrangea*, *Erythrina*, *Euphorbia*, *Loasa*, *Ardisia*, *Vincetoxicum*, *Lycianthes*, *Solanum* and *Capsicum*.

Standley, P. C. The republic of Salvador. Smithsonian Inst. Rept. **1922**: 309–328. *pl. 1–16.* 1924.

Starkey, R. L., and Henrici, A. T. The occurrence of yeasts in soil. Soil Sci. **23**: 33–44. *pl. 1.* Ja 1927.

Stewart, G. Correlated inheritance in wheat. Jour. Agr. Res. **33**: 1163–1192. *f. 1–4.* 15 D 1926.

Stout, A. B. A new seedless grape. Jour. N. Y. Bot. Gard. **28**: 20–23. *f. 1.* Ja 1927.

If worthy of general culture, the variety will be more adequately described, named and distributed.

Sweet, A. T. Interesting trees of Haiti. Am. For. & For. Life **33**: 31–35. Ja 1927.

Sydow, H. Fungi in itinere costaricensi collecti. II. III. Ann. Mycologici **24**: 283–426; **25**: 1–160. *f. 1–8.* 8 D 1926; 10 Ap 1927.

Tanaka, T. Taxonomic aspect of tropic citriculture. Philipp. Agr. Rev. 19: 179–184. O 1926.

Taylor, W. R. The marine flora of the Dry Tortugas. Rev. Algologique **2**: 113–135. Je 1925.

Teodoro, N. G. Philippine mycological and phytopathological literature index, I. Philipp. Agr. Rev. **19**: 275–291. O 1926.

Teodoro, N. G., and Bogayong, J. R. Rice diseases and their control. Philipp. Agr. Rev. **19**: 237–241. *pl. 55–63.* O 1926.

Teodoro, N. G., and Gomez, E. T. Coffee diseases and their control. Philipp. Agr. Rev. **19**: 249–257. *pl. 70, 71.* O 1926.

Teodoro, N. G., and Serrano, F. B. Abaca heart-rot and bunchy-top diseases and their control. Philipp. Agr. Rev. **19**: 243–247. *pl.* 64–69. O 1926.

Thiessen, R. Origin of the boghead coals. U. S. Geol. Surv. Prof. Paper 132^{I}: 121–137. *pl. 27–40.* 14 My 1925.

Thom, C., and Church, M. B. The Aspergilli. i–ix, 1–272. *f. 1–3 + pl. 1–4.* Baltimore, Williams & Wilkins, 1926.

Thompson, N. E., and Robbins, W. W. Methods of eradicating the common barberry (*Berberis vulgaris* L.). U. S. Dept. Agr. Bull. 1451: 1–46. D 1926.

Thone, F. Advantages of river canyons for ecological study. Trans. Illinois S. Acad. Sci. **15**: 202–207. *f. 1–3.* 1922.

Tims, E. C. The influence of soil temperature and soil moisture on the development of yellows in cabbage seedlings. Jour. Agr. Res. **33**: 971–992. *f. 1–11.* 15 N 1926.

Toro, R. A. Mycological notes. I. Jour. Dept. Agr. Porto Rico **10**^{2}: 11–22. *f. 1 + pl. 1.* Ap 1926.

Genus *Toroa*, 1 species, and several combinations described as new.

Transeau, E. N. The genus *Mougeotia*. Ohio Jour. Sci. **26**: 311–338. *pl. 1–7.* N 1926.

Trenk, F. B. The occurrence of hickories in Iowa in relation to soil types. Proc. Iowa Acad. Sci. **32**: 143–155. *f. 1–7.* "1925" 1926.

Trenk, F. B. Some soil and moisture relationships of sweet gum and river birch in southern Maryland. Proc. Iowa Acad. Sci. **32**: 133–142. *f. 1–3.* "1925" 1926.

Uphof, J. C. T. The floral behavior of some Eriocaulaceae. Am. Jour. Bot. **14**: 44–48. 29 Ja 1927.

Uphof, J. C. T. Die Tahiti-limonelle, eine zum anbau empfehlenswerte varietat. Tropenpfl. **29**: 425–427. *illust.* N 1926.

Uppal, B. N. A provisional list of the species of *Septoria* in Iowa. Proc. Iowa Acad. Sci. **32**: 189–199. "1925" 1926.

Walker, J. C. *Botrytis* neck rots of onions. Jour. Agr. Res. **33**: 893–928. *f. 1–6.* 15 N 1926.

Warner, S. R. Distribution of native plants and weeds on certain soil types in eastern Texas. Bot. Gaz. **82**: 345–372. 30 D 1926.

Wehmeyer, L. E. A biologic and phylogenetic study of the stromatic Sphaeriales. Am. Jour. Bot. **13**: 575–645. "D 1926" 15 Ja 1927.

Weiss, F. Seed germination in the gray birch, *Betula populifolia.* Am. Jour. Bot. **13**: 737–742. "D 1926" 15 Ja 1927.

West, Mrs. S. B. Bird-foot violet. Am. Bot. **33**: 27–29. Ja 1927.

Wilson, E. H. The ten most useful shrubs and vines. House & Gard. **51**: 102, 103, 142, 146, 148, 150. *illust.* Ja 1927.

Wilson, J. K., and Lyon, T. L. The growth of certain microorganisms in plants and in unplanted soil. N. Y. (Cornell) Agr. Exp. Sta. Memoir 103: 1–25. O 1926.

Winkler, A. J. The influence of pruning on the germinability of pollen and the set of berries in *Vitis vinifera.* Hilgardia **2**: 108–124. *f. 1–4.* N 1926.

Winkler, H. Musaceae. Pflanzenareale **1**^{2}: 19–20. *pl. 11, 12.* 1926.

Woodworth, C. M. Heritable characters of maize. XXVIII. Barren-sterile. Jour. Hered. **17**: 405–411. *f. 4–8.* "N 1926" 15 Ja 1927.

Youden, W. J., and Denny, F. E. Factors influencing the pH equilibrium known as the isoelectric point of plant tissue. Am. Jour. Bot. **13**: 743–753. *f. 1–3.* "D 1926" 15 Ja 1927.

CORRECTIONS

for Bull. Torrey Bot. Club, vol. 54, no. 3, March, 1927

For "*Lamprothamnus alopercoides*" read "*Lamprothamnus alopecuroides*" on pages 188, 192, 195, 213, 216, 217, 227, and 229.

For "Henry Allen Gleason" read "Henry Allan Gleason" on front page of cover.

On page 233 add "Leaves serrate or dentate never creno-serrate; summer shoots glabrous or tomentose" as the second main lead of the key, aligning this on the left with "Leaves creno-serrate; summer shoots tomentose."

On page 247 add foot-note "[6]Ashe, Bull. Charleston, S. Car., Mus. 32. 1925."

Additions to the genus Phoradendron

WILLIAM TRELEASE

In the decade since the publication of my monograph of this exclusively American genus[1] a number of current collections have been submitted to me for determination, and among them the following species have been recognized as new. Preoccupation with Piperaceae has so engrossed my attention during recent visits to the great herbaria that I have not examined collections which may have found their way into these herbaria directly, so that it is quite possible that added novelties of which I am ignorant may have been collected. Descriptions of the species here noted were given at the time to the botanists from whom specimens were received, so that it is possible that others than the three cited below may have been published already under the names here used; but if such publication has escaped my notice, no harm can come from repetition here.

1. **Phoradendron Goldmani** n. sp.

(BOREALES—FLAVESCENTES)

Rather large, not forked, the moderate branches without cataphyls, dioecious. Internodes rather short (2–5 × 20–50 mm.), at first papillate-puberulent like the very young foliage. Leaves elliptic- or obovate-oblong, very obtuse, about 1 × 3 cm., very shortly cuneate-subpetioled. Spikes solitary, elongated (90 mm. in fruit), papillate-puberulent, with some seven elongated joints annularly 6- to 12-flowered when pistillate; peduncle commonly of 2 joints 5 mm. long; scales truncate-connate, papillate and papillate-ciliate. Fruit apparently white, subglobose, glabrous, about 4 mm. in diameter, in widely separated whorls; sepals glabrous, closely inflexed.

Eastern Sierra Madre region of Mexico.—The type from Camargo, Tamaulipas (Goldman 748, 749, Jan. 1902).

2. **Phoradendron huricolum** n. sp.

(AEQUATORIALES—ANGUSTIFOLIAE)

Scarcely forked, the moderate branches with basal cataphyls only, dioecious. Internodes rather short (2–3 × 40–50 mm.),

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[1] The Genus Phoradendron, Urbana, Illinois, The University of Illinois. 1916.

[The BULLETIN for May (54: 383–470) was issued 18 June 1927.]

smooth, from somewhat 2-edged becoming 4-sided. Cataphyls a single basal pair, short. Leaves oblong-lanceolate, obtuse, 1.3 × 8 cm., finely basinerved, cuneately subpetioled for about 5 mm. Spikes subsolitary, short (about 10 mm.), slender, smooth, with 2 or 3 oblong joints some 6-flowered in 4 + 2 series when pistillate; peduncle scarcely 2 mm. long; scales subtruncately connate. Fruit (immature) subglobose, 2 mm. in diameter, smooth; sepals closely inflexed.

Venezuelan region.—The type from Venezuela.

Specimens examined:—Venezuela. Vicinity of Cristobal Colon (Broadway 1778, on *Hura crepitans*,—the type at the New York Botanical Garden).

3. **Phoradendron pomasquianum** n. sp.

(AEQUATORIALES—ANGUSTIFOLIAE)

More or less forked or fastigiately branched, the slender and rather short branches with basal cataphyls only. Dioecious?. Internodes rather short (1–2, or below 5, × 25–40 mm.), smooth, terete or evanescently flattened. Cataphyls a single basal pair or followed at a small distance by a second pair, spreading and becoming white-margined. Leaves narrowly oblong, obtuse, scarcely 1 × 50 mm., finely basinerved, cuneately slender-petioled for scarcely 10 mm. Spikes solitary in the axils, rather short (scarcely 30 mm.), slender, smooth, with about 4 turbinate joints 12- to 20-flowered in 4 series when pistillate; peduncle about 5 mm. long. Fruit (immature) oblong, 2–3 × 4 mm., smooth; sepals inflexed.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador. High plains near Pomasqui at 2500 m. (Sodiro 22,—the type at the University of Illinois).

4. **Phoradendron pseudo-angustifolium** n. sp.

(AEQUATORIALES—ANGUSTIFOLIAE)

Closely resembling *P. angustifolium* in habit, measurements and details, except that the leaves are thicker and for this reason obscurely if at all nerved.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador, Las Juntas (Rose, Pachano and Rose 23212,—the type as sheet 1022732 in the U. S. National Herbarium).

5. **Phoradendron Roseanum** n. sp.

(AEQUATORIALES—ANDINAE)

Very large and coarse, varnished, scarcely forked, the long branches apparently with basal cataphyls only, probably dioecious. Internodes rather long (6–8 × 70–100 mm. or more), smooth, ancipital or 2-winged becoming terete. Cataphyls?. Leaves falcately lanceolate, large (as much as 4 × 20 cm.), rather obtuse, about 7-nerved, cuneately wing-petioled for about 10 mm. Spikes commonly clustered, long (60–80 mm. in fruit), with about 4 turbinate joints some 40- to 50-flowered in 6 series; peduncle scarcely 5 mm. long; scales scarcely ciliate, subtruncate. Fruit (reddish?) globose, smooth, about 3 mm. in diameter; sepals closely inflexed.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador, Las Juntas (Rose, Pachano and Rose 23213, Sept. 28, 1918,—the type, as sheet 1022733, in the U. S. National Herbarium).

Marked by its glossy stem and infloresence and large elongated leaves: differing from other members of the group in its very long spikes with more numerous 6-ranked flowers.

6. **Phoradendron pifoense** n. sp.

(AEQUATORIALES—ANDINAE)

Scarcely forked, the rather long branches with basal cataphyls only, dioecious?. Internodes moderate (2–4 × 40–50 mm.), smooth, at first ancipitally flattened. Cataphyls basal, solitary. Leaves subfalcately lanceolate, obtuse, 2.5–3 × 8–9 cm., or becoming as much as 6 × 15 cm., rather sharply 7-nerved, cuneately subpetioled for scarcely 10 mm. Spikes more or less clustered in the axils, thick but only moderately (30–50 mm.) long, with about 4 oblong-obovoid joints about 20-flowered in 4 + 2 series when pistillate; peduncle scant 3 mm. long; scales somewhat ciliate-scarious-margined, subtruncate. Fruit red, dull, globose, 3–4 mm. in diameter; sepals inflexed.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador. Pifo (Mille 32,—the type at the University of Illinois); also reported for Chillos Valley at 2600 m.

7. **Phoradendron Pachanum** n. sp.

(AEQUATORIALES—ANDINAE)

More or less divaricately forking, the rather long branches with basal cataphyls only, androgynous. Internodes moderate or rather stout (2–4 × 25–50 mm.), smooth and drying glossy, little compressed. Cataphyls a basal pair, rounded. Leaves obliquely or dimidiately sublanceolate, obtuse, 2.5–5 × 9–14 cm., about 5-nerved, wing-petioled for 10 mm. Spikes clustered, rather short (scarcely 30 mm.), with about 4 oblong or slightly clavate joints some 24-flowered in 4 + 2, or 6, series,—

the uppermost short and few flowered; peduncle 2–4 mm. long. Fruit subglobose, smooth, 3–4 mm. in diameter; sepals closely inflexed.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador, Ambato, Tungurahua (A. Pachano 246,—the type in the U. S. National Herbarium).

8. **Phoradendron brachypodum** n. sp.

(AEQUATORIALES—POLYGYNAE)

With basal cataphyls only on the branches and androgynous?. Internodes rather long (3–4 × 40–50 mm.), smooth, the upper ancipitally compressed, scarcely dilated at the nodes. Cataphyls a single pair, closely basal, tubular. Leaves lance-oblong or oblanceolate, very obtuse, 1.5–2.5 × 5–8 cm., cuneately contracted for 5–10 mm. at base, dull, faintly subpinnately 5- or 7-nerved, spikes solitary in the axils, thick, apparently to become moderately (some 50 mm.) long, with 5 or 6 stout subclavate-oblong joints 60- to 80-flowered in about 6 series; peduncle 5 mm. long, the succeeding joint floriferous; scales tubular-subtruncate. Fruit?.

Andean region.—The type from Colombia.

Specimens examined:—Colombia. San Cristobal, near Usme (Brother Ariste-Joseph A 919,—the type).

9. **Phoradendron guascanum** n. sp.

(AEQUATORIALES—OBLIQUAE)

Large, brittle, with basal cataphyls only?, androgynous?. Internodes thick (5–10 mm.), granular-corrugated, terete or at first compressed, but little dilated at the nodes. Cataphyls apparently a nearly basal pair, followed at intervals of 1 or 2 cm. by 2 or 3 others, tubular. Leaves obliquely obovate or subdimidiately elliptic, very obtuse, becoming 10 × 13 cm., cuneately thick-petioled for about 10 mm., pinnately about 10-nerved with the midrib heavy and prominent, drying thick, hard and glossy. Spikes elongated?, with several subclavate thick joints, some 36-flowered in 6 series; peduncle?; scales tubular-subtruncate. Fruit?.

Andean region.—The type from Colombia.

Specimens examined:—Eastern paramos of Guasca, toward Gacheta (Brother Ariste-Joseph B 60, in 1921,—the type).

The obvious pinnate nerving of this species is in disaccord with the obscure (really palmate?) nerving of *P. obliquum*.

10. **Phoradendron Millspaughii** n. sp.

(AEQUATORIALES—QUADRANGULARES)

Scarcely forking, the moderate branches with basal cataphyls only, androgynous?. Internodes rather short (2 × 30–50 mm.), essentially smooth, quadrangular, somewhat compressed at the nodes. Cataphyls a single nearly basal pair, nearly separate, pale-margined. Leaves oblanceolate-oblong, submucronately obtuse; 1–1.5 × 4–6 cm., cuneately narrowed rather than petioled. Spikes solitary, moderate (30–50 mm.), with 3 or 4 elongated joints turbinately about 20-flowered in 4 or 4 + 2 series; peduncle scarcely 2 mm. long. Fruit (immature) ellipsoid, smooth, 3 mm. long: sepals closely inflexed.

Yucatan region.—The type from Yucatan.

Specimens examined:—Mexico. Forests of Suitun, Yucatan (Gaumer & Sons 23827, part 2, 1917,—the type, in the Herbarium of the Field Museum, as sheet 466268).

Closely related to *P. Gaumeri*, but distinct in its elongated leaves and more turbinately flowered spikes: and with foliage comparable with the Isthmian *P. ceibanum*, the Pacific *P. Townsendi*, and some forms of the Mexican *P. tamaulipense*.

11. PHORADENDRON RUSBYANUM Trel.

In Rusby, Mem. New York Bot. Garden **7**: 234. 1927.

(AEQUATORIALES—QUADRANGULARES)

Brazilian region.—The type from Bolivia.

Specimens examined:—Reyes, Bolivia (Rusby 1714,—the type).

12. PHORADENDRON CAERULESCENS Trel.

In Britton, Bull. Torr. Bot. Club **48**: 330. 1921.

(AEQUATORIALES—EMARGINATAE)

Venezuelan region.—The type from Trinidad.

Specimens examined:—Chacachacare Island, Trinidad (Britton and Hazen 1726,—the type); also from the same locality, on *Capparis* (Britton, Freeman and Watts, 2701, 2708).

13. PHORADENDRON CHAGUARAMASANUM Trel.

In Britton, Bull. Torr. Bot. Club **48**: 330. 1921.

(AEQUATORIALES—EMARGINATAE)

Venezuelan region.—The type from Trinidad.

Specimens examined:—Chaguaramas, Trinidad (Britton 2718,—the type).

the uppermost short and few flowered; peduncle 2–4 mm. long. Fruit subglobose, smooth, 3–4 mm. in diameter; sepals closely inflexed.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador, Ambato, Tungurahua (A. Pachano 246,—the type in the U. S. National Herbarium).

8. **Phoradendron brachypodum** n. sp.

(AEQUATORIALES—POLYGYNAE)

With basal cataphyls only on the branches and androgynous?. Internodes rather long (3–4 × 40–50 mm.), smooth, the upper ancipitally compressed, scarcely dilated at the nodes. Cataphyls a single pair, closely basal, tubular. Leaves lance-oblong or oblanceolate, very obtuse, 1.5–2.5 × 5–8 cm., cuneately contracted for 5–10 mm. at base, dull, faintly subpinnately 5- or 7-nerved, spikes solitary in the axils, thick, apparently to become moderately (some 50 mm.) long, with 5 or 6 stout subclavate-oblong joints 60- to 80-flowered in about 6 series; peduncle 5 mm. long, the succeeding joint floriferous; scales tubular-subtruncate. Fruit?.

Andean region.—The type from Colombia.

Specimens examined:—Colombia. San Cristobal, near Usme (Brother Ariste-Joseph A 919,—the type).

9. **Phoradendron guascanum** n. sp.

(AEQUATORIALES—OBLIQUAE)

Large, brittle, with basal cataphyls only?, androgynous?. Internodes thick (5–10 mm.), granular-corrugated, terete or at first compressed, but little dilated at the nodes. Cataphyls apparently a nearly basal pair, followed at intervals of 1 or 2 cm. by 2 or 3 others, tubular. Leaves obliquely obovate or subdimidiately elliptic, very obtuse, becoming 10 × 13 cm., cuneately thick-petioled for about 10 mm., pinnately about 10-nerved with the midrib heavy and prominent, drying thick, hard and glossy. Spikes elongated?, with several subclavate thick joints, some 36-flowered in 6 series; peduncle?; scales tubular-subtruncate. Fruit?.

Andean region.—The type from Colombia.

Specimens examined:—Eastern paramos of Guasca, toward Gacheta (Brother Ariste-Joseph B 60, in 1921,—the type).

The obvious pinnate nerving of this species is in disaccord with the obscure (really palmate?) nerving of *P. obliquum*.

10. **Phoradendron Millspaughii** n. sp.

(AEQUATORIALES—QUADRANGULARES)

Scarcely forking, the moderate branches with basal cataphyls only, androgynous?. Internodes rather short (2 × 30–50 mm.), essentially smooth, quadrangular, somewhat compressed at the nodes. Cataphyls a single nearly basal pair, nearly separate, pale-margined. Leaves oblanceolate-oblong, submucronately obtuse; 1–1.5 × 4–6 cm., cuneately narrowed rather than petioled. Spikes solitary, moderate (30–50 mm.), with 3 or 4 elongated joints turbinately about 20-flowered in 4 or 4 + 2 series; peduncle scarcely 2 mm. long. Fruit (immature) ellipsoid, smooth, 3 mm. long: sepals closely inflexed.

Yucatan region.—The type from Yucatan.

Specimens examined:—Mexico. Forests of Suitun, Yucatan (Gaumer & Sons 23827, part 2, 1917,—the type, in the Herbarium of the Field Museum, as sheet 466268).

Closely related to *P. Gaumeri*, but distinct in its elongated leaves and more turbinately flowered spikes: and with foliage comparable with the Isthmian *P. ceibanum*, the Pacific *P. Townsendi*, and some forms of the Mexican *P. tamaulipense*.

11. PHORADENDRON RUSBYANUM Trel.

In Rusby, Mem. New York Bot. Garden **7**: 234. 1927.

(AEQUATORIALES—QUADRANGULARES)

Brazilian region.—The type from Bolivia.

Specimens examined:—Reyes, Bolivia (Rusby 1714,—the type).

12. PHORADENDRON CAERULESCENS Trel.

In Britton, Bull. Torr. Bot. Club **48**: 330. 1921.

(AEQUATORIALES—EMARGINATAE)

Venezuelan region.—The type from Trinidad.

Specimens examined:—Chacachacare Island, Trinidad (Britton and Hazen 1726,—the type); also from the same locality, on *Capparis* (Britton, Freeman and Watts, 2701, 2708).

13. PHORADENDRON CHAGUARAMASANUM Trel.

In Britton, Bull. Torr. Bot. Club **48**: 330. 1921.

(AEQUATORIALES—EMARGINATAE)

Venezuelan region.—The type from Trinidad.

Specimens examined:—Chaguaramas, Trinidad (Britton 2718,—the type).

14. **Phoradendron Baileyae** n. sp.

(AEQUATORIALES—LIGAE)

Somewhat pseudo-dichotomous, the moderately long branches with basal cataphyls only, glabrous, androgynous?. Internodes moderate or rather short (2–3 × 20–40 mm.), ancipitally or the uppermost slightly rhomboidally compressed. Cataphyls a single nearly basal pair. Leaves oblanceolate-oblong and narrow (scarcely 1 × 5 cm.) or the lower obovate-oblong and broader (1.5 cm.) rounded or submucronate at apex, cuneately narrowed to the scarcely petioled base, drying thick but rather evidently 5-nerved from the base. Spikes short (10–15 mm.), with about 3 rather slender nearly cylindric joints about 4-flowered near the middle; peduncle 2 mm. long, with subtruncately connate scales. Fruit yellow?, ellipsoid, 3 × 4 mm., smooth, with widely separated sepals.

Venezuelan region.—The type from the vicinity of Ciudad Bolivar, on the Orinoco (L. H. and Ethel Zoe Bailey 1401, Feb. 28, 1921).

15. **Phoradendron lapatanum** n. sp.

(AEQUATORIALES—HEXASTICHAE)

Scarcely forked, the rather long branches with basal catapyls only, androgynous?. Internodes moderate (3–6 × 30–70 mm.), somewhat microscopically papillate, ancipital or somewhat rhombic and dilated upwards, becoming terete. Cataphyls usually a single pair, but sometimes 2–3 pairs within less than 1 cm. of the base, subtruncately bifid, ciliate. Leaves round-ovate to obovate, very obtuse, narrowly revolute, 2–4 × 4–5 cm., drying dark and chartaceous with percurrent midrib, obscurely pinnately veined, petioled for about 10 mm. Spikes mostly solitary, rather long (20, becoming 40–50 mm.), with about 4 somewhat fusiform joints scarcely over 12-flowered in 6 series; peduncle scarcely 8 mm. long, sometimes with a basal pair of sterile or floriferous scales. Fruit apparently red, globose, slightly cellular-papillate, 4 mm. in diameter: sepals closely inflexed.

Antillean region.—The type from Cuba.

Specimens examined:—El Corte, Sta. Tomas, Peninsula of Lapata, Cuba (Roig & Cremata 2198, in 1920,—the type at the New York Botanical Garden).

Differing from *P. hexastichum* in its darkening smaller and often obovate leaves, and its larger differently colored fruit.

16. PHORADENDRON BARAHONAE Urb. & Trel.

In Fedde, Repert. 13: 444. 1914,—as Phoradendrum.

(AEQUATORIALES—PTERONEURAE)

Antillean region.—The type from Hispaniola.

Unfortunately the prior publication of this herbarium name was overlooked when Wright's herbarium name *P. cerinocarpum* was adopted in 1916.

17. **Phoradendron canzacotoi** n. sp.

(AEQUATORIALES—TUNAEFORMES)

Scarcely forking, the elongated branches with basal cataphyls only, androgynous?. Internodes rather short (5–10 × 20–40 mm.), thin-winged from a terete axis 3–5 mm. in diameter rather than flattened, slightly papillate, not striately ridged. Cataphyls a single short annular basal pair. Leaves minute, scale-like, marcescent. Spikes more or less clustered, very short (scarcely 5 mm.), of a single joint about 15-flowered in 4 series; peduncle very short. Fruit?.

Andean region.—The type from Ecuador.

Specimens examined:—Ecuador, Subtropical forest, Canzacoto, at 2,000 m. (Sodiro 14,—the type at the University of Illinois).

THE UNIVERSITY OF ILLINOIS,
URBANA, ILLINOIS.

Fig. 12. Antipodal end of embryo sac of *E. Philadelphicus*, at the time of fusion of the polar nuclei, showing the lower, much enlarged cell containing two nuclei and several food particles. The two cells above it are the antipodal cells in the constricted area of the embryo sac.

Fig. 13. Antipodal end of embryo sac of *E. Philadelphicus* at the time of fertilization showing the much enlarged lower cell containing fourteen free nuclei. The cell nearest the egg apparatus end of the embryo sac is being absorbed.

Fig. 14. Antipodal cells of *E. Philadelphicus* at a time when a young embryo is present in the upper end of the embryo sac. The cells in the constricted area are being absorbed. The enlarged basal cell has four nuclei, the upper one of which resembles an egg cell, *e*, and the two just below it resemble polar nuclei, *p.n.*

Fig. 15. Section of an embryo sac of *E. Philadelphicus* showing a characteristic antipodal region of four cells. Of the two nuclei of the basal cell, the upper one, *e*, resembling an egg nucleus and the one just below it an endosperm nucleus, *e.n.* The egg apparatus is aborted and shows only as a line of disorganized material, *dis.* An extra layer of tapetal-like tissue, *n.t.*, has developed where the egg apparatus should be.

Fig. 16. Section of an embryo sac of *E. Philadelphicus* showing the enlarged antipodal cell still present after an embryo, *em.*, has grown large enough to fill the egg apparatus end of the sac. A portion of endosperm, *en.*, is still present and also a remnant of an antipodal cell, *ant.*, of the constricted area between the two ends.

Fig. 17. Anomaly in the development of the embryo sac of *E. Philadelphicus*. A single longitudinal row of seven cells composes this embryo sac. A pollen tube, *p.t.*, is present in the upper end.

Fig. 18. Normal achene developed in *E. Philadelphicus* when an open head is decapitated.

Fig. 19. Empty undeveloped achene of *E. Philadelphicus* which results from unopened decapitated heads. Evidently fertilization is prevented.

The production of intumescences in Transparent apple by ethylene gas as affected by external and internal conditions

RAYMOND HAROLD WALLACE

(WITH TWO TEXT FIGURES AND PLATE 34)

Dating from the classic work of Nägeli in 1893 on oligodynamic phenomena a vast mass of physiological data has been accumulated upon the effects of extremely small amounts of various organic and inorganic substances in modifying the growth and inducing specific responses of various types in plants. Sensitiveness to certain compounds in a degree not before imagined has been demonstrated. It has been shown recently that mere traces of boron, zinc, manganese, and other elements may be essential for the growth and maturity of some species. We now know that plants respond to concentrations of toxic and stimulating substances which are far below the range of measurement by any *in vitro* physical or chemical means at our command. Neljubow (1901), Crocker and Knight (1908), and others have shown the sensitiveness and the extreme variation in the reactions of plants to minute amounts of ethylene, and I have given a preliminary report on the production of intumescences on woody twigs by low concentrations of this gas.

LITERATURE REVIEW

Physiological effects of ethylene

That ethylene is a substance which can induce a wide variety of effects in living organisms is well known. The earlier data relate primarily to the toxic effects shown by etiolated seedlings, roots, and other plant parts when exposed to very low concentrations of this gas. Neljubow (1901) reported that the epicotyls of etiolated seedlings of pea, *Vicia sativa*, *Ervum lens*, *Lathyrus odoratus*, and *Tropaeolum* grow horizontally in the presence of ethylene, acetylene, or illuminating gas. A concentration of 1 part of ethylene to 1,000,000 parts of air affected the direction of growth, while 1 part of ethylene to 40,000 parts of air caused the death of the seedlings. Crocker and Knight (1908) found the buds and flowers of carnations to be very susceptible to injury by ethylene gas. They report that the closing of the flowers of the carnation occurred in a concentration of 1 part of ethylene to 2,000,000 parts of air. A concentration of 1 part of ethylene to 40,000 parts of air was lethal to young buds and prevented the opening of buds already showing petals. E. M. Harvey (1913), working in the same laboratory, found that the leaves of *Ricinus communis* exhibit what he calls nastic droopings in a concentration of 1 part of ethylene to 10,000,000 parts of air. These results show that some plants or plant parts may be seriously injured or killed by extremely low concentrations of ethylene, while others may exhibit definite nastic or tropic responses.

Ethylene gas induces hypertrophy and hyperplasia in the tissues of some plants. Harvey and Rose (1915) found that swellings developed in the root cortex of seedlings of *Catalpa speciosa* and *Ailanthus* after exposures of from five to twenty-one days to various concentrations of ethylene or illuminating gas. Similar tests with *Gleditschia* gave no swellings. Both hypertrophy of the cortical parenchyma and hyperplasia of the phellogen were said to be involved. Abnormal tissues also developed in the cortex of *Hibiscus*, *Syringa*, *Diervilla*, *Ricinus*, *Ulmus*, croton, and pear, when only a small current (about 40 cc. daily) of illuminating gas was used. They thought that ethylene was mainly responsible for these formations.

Doubt (1917) extended the work by using two- or three-year-old trees and allowing various concentrations of the gas to flow around the roots continuously for from fifteen to ninety days. Her results were similar to those of Harvey and Rose. She reports all proliferated tissue to be external to the vascular cylinder.

More recently ethylene has been used to hasten bleaching or the disappearance of chlorophyll from various plant parts. Denny (1924) found that the yellowing of lemons was greatly hastened by exposing them to traces of ethylene. He also found that ethylene produced a definitely increased rate of respiration when in concentrations as low as 1 part to 1,000,000 parts of air. R. B. Harvey (1925) found that ethylene hastened the disappearance of chlorophyll from the leaves of celery. Rose (1925) found a similar effect in the case of green fruits of tomato. He also reports using ethylene successfully to induce more rapid sprouting of dormant potato tubers.

Luckhardt and Carter (1923) established the fact that ethylene gas, when inhaled by animals, including man, has strong anaesthetic properties. A mixture of 90 per cent of ethylene and 10 per cent of oxygen anaesthetized all animals studied, but the time required for complete anaesthesia was found to vary somewhat with the individual and species. The characteristics of ethylene anaesthesia are somewhat similar to those produced by nitrous oxide, but are very different from those produced by ether or chloroform. Ethylene seems to cause no marked stimulation or depression of the vagus centers. "Respiration" and blood pressure remain almost normal. It is now used quite extensively in some medical institutions.

One of the most peculiar of the physiological effects reported for ethylene gas is that noted by Fujii (1925). He observed, while making a study of *Isoetes*, that occasionally the antheridia liberated their sperms with great readiness. At other times it was impossible for him to induce their escape by any means at his command. Numerous experiments finally convinced him that the slight amount of illuminating gas set free in the room at the time he lighted the gas lamp for his microscope was responsible for the effect. Further experiments indicated that in this case also ethylene is the active constituent of the illuminating gas.

The formation of intumescences in plants

Pathological outgrowths of the type known as intumescences are found to occur in numerous kinds of plants and plant tissues. While these malformations most frequently appear on leaves and stems, they are not uncommonly found on roots and may even occur on flowers and fruits. Numerous hypotheses have been advanced as to the conditions which induce or favor the production of these peculiar outgrowths. Sorauer, in one of his early papers (1886) concludes, as a result of extensive experiments on intumescences in leaves, that their formation is to be regarded as a symptom of a metabolic disturbance due to an excess of water during a period of low assimilation. Later (1899) he repeats this hypothesis, but stresses also the contributory effect of a high temperature. He says that a high temperature plus an excessive water supply in the case of plants whose "assimilative activity" is low because of weak illumination, will result in the production of intumescences. Quoting him directly: "Since in two cases (*Ficus elastica* and *Impatiens Sultani*) I have already succeeded in producing intumescences by such means, the appearance of such structures may now be regarded with certainty as a symptom of an abnormal rise in temperature and excessive water supply."

Excessive water supply in the soil or in the atmosphere is given by many investigators as the determining condition in intumescence formation. Atkinson (1893a) reports a very interesting oedema upon tomato plants which were grown in a forcing house. These plants exhibited numerous elevated areas of granular appearance on the surfaces of the leaves, petioles, and stems. The appearance was so suggestive of a bacterial or fungous infection that many experiments were made before it was established that the disease was of non-parasitic origin. Atkinson concluded that the chief physiological cause for the disease was an excessive water content, due to high root pressure and low transpiration. The weak illumination and high humidity present in the experimental greenhouse permitted only a very low rate of transpiration as well as allowing only a minimal rate of photosynthesis. He was able to produce similar intumescences at will by injecting the shoots with an excess of water. He reports (1893b) a somewhat similar case of oedema on the stems and branches of apple. The elevations arose from the phellogen and were from one-eighth to one-fourth inch in length and almost as wide, and appeared as blisters on the bark of the trees. This diseased condition appeared in trees whose transpiring powers had been made low by severe top pruning, but whose root systems had not been molested and were therefore capable of rapid absorption. He concluded, in this case, that the outgrowths were due to excessive root pressure which was developed as the result of a high rate of absorption by the roots and a low rate of transpiration from the aerial parts of the plants.

Steiner (1905) found intumescences on the leaves of *Ruellia formosa* and *Aphelandra Porteana*, and concluded from experiments that they were developed in response to excessive humidity. They did not appear when the leaves were immersed in water or kept in darkness. Douglas (1907) produced a great number of intumescences upon the stems and leaves of potato plants by enclosing the plants in moist atmospheres under bell-jars. They formed readily in either weak or strong light, but did not appear when the plants were kept in total darkness.

Intumescences in woody stems have been induced by covering them with a relatively impervious layer of paraffin oil, vaseline, etc. Wisniewski (1910) painted twigs of *Ficus australis* and *Ficus elastica* with paraffin oil and kept them in laboratory air. In a week they developed in their lenticels intumescences as much as 4 mm. in diameter. Twigs, untreated by paraffin oil, but placed under bell-jars and partially immersed in water, produced some small intumescences in their lenticels on the immersed portions of the stems, while the portions in the humid air above were free from outgrowths. From this he concluded that, while a reduction of transpiration is to be regarded as one of the main conditions influential in causing intumescences, other conditions, yet poorly understood, play a part as well.

Schilling (1915) found that the response reported by Wisniewski for two species of *Ficus* was characteristic of many species of plants. He reported that lenticel intumescences or excrescences appeared upon stems of *Aesculus hippocastanum*, *Spiraea concinna*, *Philodendron pinnatifidum*, *Ascocarpus incisa*, *Sambucus nigra*, and numerous other woody plants when the stems were painted with vaseline or paraffin oil. In general, plants having lenticels were more prone to form intumescences than those lacking them. Schilling concludes that these abnormal developments are not due to any chemical stimulus from the vaseline or paraffin oil. He regards retardation of transpiration as the chief condition involved, but also mentions the possibility that oxygen deficit may play a rôle as well. Tests indicated that the osmotic pressure of the abnormal cells was greater than that of normal cells.

Hahn, Hartley, and Rhoades (1920) reported tissue formation very similar to that noted above on woody stems as occurring on the roots of a great variety of coniferous seedlings when grown under conditions of excessive soil moisture. The disease was present in about equal degree in both strong and weak seedlings, which, they thought, indicated that it was a physiological derangement not dependent on the presence of a parasitic organism. Top pruning decreased the intensity of the disorder while root pruning increased it. The writers were doubtful as to the major determining condition, but were inclined to think it was either a deficit of oxygen or an excess of carbon dioxide rather than an excessive sap pressure.

Special light relations, as well as an excessive supply of moisture, have been considered as favoring markedly the production of abnormal outgrowths upon plants. Although the reports concerning the influence of light are conflicting, a survey of the literature indicates that light may either favor or inhibit the response, according to the plant materials and the other experimental conditions involved.

One group of investigators has been inclined to look upon weak illumination as favorable to intumescence formation. Sorauer (1886) held that low "assimilative activity" resulting from weak illumination tends to favor the production of such malformations. He also states (1899) that intumescences form most often during the fall and winter when the assimilative activities of the plants are lowest. Likewise, Atkinson (1893a) regarded weak light as favoring intumescence formation in the stems and leaves of the tomato. He associates the production of intumescences both with the low photosynthetic activity that results from poor illumination and with the development of weak, watery tissue that occurs in low light intensity. The formation of the intumescences described by Prillieux (1892) on the leaves of the pink and by Norack (1901) on the leaves of the grape was observed to occur only in weak illumination.

Küster (1903b) produced artificial intumescences on the leaves of *Populus tremula* by floating the leaves on water. These outgrowths formed both in light and in darkness, but in strong light they appeared usually on the side of the leaf nearest the water, regardless of whether this was morphologically the dorsal or the ventral side. Their formation on the under side was considered to be associated with retardation in the rate of transpiration on that side.

Another group of investigators has found that rather strong light is essential to the production of intumescences. Dale (1901) reported that the peculiar outgrowths which often occur on the leaves, petioles, and green stems of *Hibiscus vitifolius* failed to appear in total darkness or in weak light. The quality of the light was also found to be significant, since the intumescences formed under white, red, or yellow light, but failed to form under blue, green, or weak light. She pointed out that a checking of the rate of transpiration was one of the necessary conditions determining the development of intumescences, but that this condition alone was not sufficient to lead to their formation. An active rate of photosynthesis was also considered to be necessary.

Viala and Pacottet (1904) drew a similar conclusion with reference to intumescences that appeared on the leaves of grapes grown under glass, since they found by experiment that these outgrowths occur only in the presence of intense light and a humid atmosphere. Only leaves directly under the glass during periods of strong illumination were affected, while those in weak light or in the shade remained normal. Von Schrenk (1905) makes a similar statement concerning the formation of intumescences on the leaves of grape. He reported, however, that the production of intumescences on cauliflower in response to chemical stimulation by copper was independent of light intensity, and occurred throughout the range of temperature and moisture conditions existing in his experiments.

Douglas (1907) held the view that light favors the production of intumescences on potato plants only in so far as it provides for the normal processes of metabolism and growth of the stems and leaves. The failure of intumescences to appear in darkness was considered to be due to a reduction of the effective water content, owing to an increased growth in length.

The data so far reviewed indicate clearly that several of the conditions comprising the physical environment may be very influential in the production of intumescences on many plants. Furthermore, there is abundant evidence that chemical conditions of the environment may have as great an effect in causing such proliferations or malformations in plant tissues. Haberlandt (1899) was able to induce the production of intumescences upon the thalli of *Conocephalus ovalus* and *C. suaveolens* by painting them with a one per cent alcoholic solution of corrosive sublimate. This treatment killed the cells of the hydathodes, or water excreting organs. Additional hydathodes were then formed by enlargement of the cells of the underlying parenchyma. Haberlandt attributed the formation of these "compensating" hydathodes to an excess pressure which he supposed developed through the failure of the normal organs to function. The new structures functioned as normal hydathodes until they dried up and died.

Von Schrenk (1905) induced the production of intumescences on the leaves of cauliflower by spraying them with various solutions of copper salts. The occurrence of these formations seemed not to be influenced by ordinary differences in atmospheric or soil conditions. Douglas (1907) produced similar outgrowths on leaves of young potato plants by treatment with like compounds. Old potato plants failed to form these structures, but instead exhibited brown areas of dead tissue. It is interesting to note that Steiner (1905) induced the formation of intumescences on the leaves of *Aphelandra Porteana* by placing them in a saturated atmosphere, but did not succeed in producing them by treatment of the leaves with copper sulphate, ammonium chloride, formic acid, pyromalic acid, potassium hydroxide, sodium hydroxide, and alcoholic and aqueous solutions of corrosive sublimate.

Smith (1917) tested the effect of various chemicals on the leaves of cauliflower. Ammonia and Carnoy's fixing fluid (ethyl alcohol and acetic acid) gave intumescences similar to those reported by Von Schrenk for copper compounds. When leaves with open stomata were exposed to Carnoy's fixing solution, dead areas appeared quickly and intumescences never developed; but when leaves with closed stomata were used, the production of intumescences resulted.

Injections of various chemicals into the pith and bark of various woody and herbaceous stems and roots have been shown to produce very striking cases of tissue development by cells that one would have supposed had lost the capacity of further growth and differentiation. In an attempt to control the blight of the chestnut by injections of chemicals into the bark of the trees, Rumbold (1915) discovered that cells of the soft bast possessed unsuspected powers of tissue formation. Following the treatment, isolated masses of xylem, phloem, and cambial tissues developed in the bark of the injected trees. She concluded that these abnormal tissues had developed in response to chemical stimulation by the injected substances.

Taylor (1916) extended this study of tissue formation resulting from injection of chemicals, experimenting on herbaceous as well as woody stems. Patches of xylem, phloem, and cambium were found to arise in the region of the soft bast in the bark of *Castanea*, but the evidence which he secured indicated that the development of these tissues was a response to the mechanical injury involved in injection and to the general injury resulting from the injected substances, rather than to a specific stimulative action of the different chemicals injected, as Rumbold had assumed. He regarded this formation of abnormal tissue as the usual wound response for the chestnut. The injection of distilled water, chloroform, ammonia, lithium carbonate, copper sulphate, and picric acid into the stems of *Polygonum*, *Helianthus*, *Phytolacca*, and *Ricinus* in every case resulted in the production of abnormalities. As a result of the injection of one or more of these agents, all kinds of tissues except epidermal and lignified elements were produced. Taylor concludes that any tissue in the stem not cutinized, suberized, or lignified may be induced to proliferate, and that the reaction is probably a response to the chemical or mechanical injury, depending upon the concentration and kind of injected material, and the extent of the mechanical injury involved in the injection.

Smith (1917) was able to simulate crown-gall formation in stems of *Ricinus communis* by injecting by-products of the metabolism of the organism *Bacterium tumefaciens* into the stems of the plants. Responses were usually absent in old nodes, but the younger nodes developed intumescences in the pith. In one case he produced experimentally "a stem within a stem" by injecting the internode with ammonia, while in another a second cylinder of xylem and phloem developed within the first. This secondary xylem-phloem tissue contained tracheae, wood fibers, cambium, etc., and was divided into bundles which were separated regularly by medullary rays. He concludes that the osmotic pressure of the injected substances removed, in some manner, the inhibiting factors which hold cell proliferation in check, and thus gives rise to these abnormal tissues; and further that the crown-gall organism excretes these metabolic products continuously and thus stimulates the host to form abnormal tissue.

Some instances are known where intumescences apparently develop in response to mechanical stimulation alone. Although

Küster (1903) held that gall formation on the leaves of *Populus tremula* by *Hermandia tremulae* and *H. globuli* was probably due directly or indirectly to toxic substances excreted by the gall forming organism, Rosen (1916) concluded from an ontogenetic study of the *Phylloxera* leaf gall that a chemical theory can not explain gall formation by this organism. His evidence led him to conclude that the proliferations of tissue which resulted in the formation of the gall were induced initially by the continual sucking action of the insect.

Bayliss (1907) observed abnormal swellings upon the roots of many plants in her investigations on the galvantropism of roots and suggested that they may have arisen in response to galvanic stimuli, or to products of electrolysis. Davis (1910) investigated this point further and concluded from his results that the intumescences were a response to wounding by the thermal or chemical changes induced by the electric current.

Wolf (1918) found intumescences upon the young leaves of cabbage which had suffered injury from blowing sand, and he was able to produce similar growths in the laboratory by means of a sand blast. He thought that the exposed cells underwent oxidation reactions which altered the hydrogen-ion concentration of the tissue and thus increased the imbibitional power of the cell colloids. This greater capacity for hydration of the cell colloids was considered to cause an excessive absorption of water which resulted in the distention and protrusion of the injured tissue.

The depth of penetration and the tissues involved in intumescence production in the bark of woody stems in response to external stimuli, such as illuminating gas, ethylene, paraffin, and other agents, have attracted no small amount of attention from investigators, but the data are still much confused. I have reviewed in a recent paper (1926) the published data bearing upon the type and extent of intumescences which develop in the bark of certain woody plants in response to ethylene or illuminating gas. In that survey the cambium, portions of the phloem, the cortex in general, or the phellogen only, are reported as involved in the formation of abnormal tissues. The lack of agreement among the investigators as to the precise tissues affected and the nature of the proliferations may be due to differences in the experimental material and methods used.

An examination of the data concerning the intumescences which occur in response to agents other than ethylene or illuminating gas shows a similar situation. Küster (1903), in describing the oedema or dropsy of *Ribes aureum*, gives what may be taken as an example of the most severe and deep-seated type of intumescence found in woody stems. This disease not uncommonly develops in nature under field conditions and is then a source of much trouble to the growers of currants and gooseberries, since *Ribes aureum* is used extensively as the stock in grafts. In this disease, abnormal tissue development results in the formation of deep longitudinal rifts in the bark of the affected plant; the disease may appear on tissues from one to several years old. All living elements from the cambium outwards may undergo hypertrophy, and in extremely severe cases even the cells of the young xylem may be affected. The walls enlarge at the expense of the cell contents, and the cells become long and sac-like. They are rich in water, but poor in all other materials. In some cases, when maceration is complete, the cells become detached from each other and form a mass of loose friable granules. The bast tissue which does not undergo hypertrophy is torn apart radially and pushed out by the enlarging tissues beneath. Oedemas similar to this have been described by Sorauer (1892) on *Pyrus communis* and by Molz (1906) on *Vitis*. Abnormal nutrient relations have been suggested as the cause.

The oedema on *Pyrus malus* described by Atkinson (1893b) was of relatively superficial origin. The epidermis was raised in blister-like patches by large vacuolated cells below, which had arisen by proliferation of the phellogen. The other tissues of the stems remained normal. The lenticel excrescences which Wisniewski (1910) induced in the stems of *Ficus elastica* and *Ficus australis* by painting them with paraffin oil extended below the phellogen. They arose by division and enlargement of the cells of the phellogen and somewhat deeper portions of the cortex.

Schilling (1916) extended the method of Wisniewski to a study of a great number of woody plants and found considerable variation in the response exhibited by the various species. Under his experimental conditions almost all kinds of plants developed excrescences in the lenticels, but *Ginkgo*, *Sophora*, *Ilex*, and *Solanum* failed to do so. Division and enlargement occurred in almost all elements of the stems except the epidermis, cork, xylem, and bast. The sieve tubes and companion cells failed to enlarge or divide and were crushed by the pressure exerted by the other, enlarging cells. The intumescences extended to, and affected the cambium in *Ribes*, *Sambucus*, *Aesculus*, *Robinia*, and *Clerodendron*.

Definite data relative to the depth of origin of the intumescences in the lenticels of the roots of conifers are not given by Hahn, Hartley, and Rhoades (1920). The fact that death sometimes resulted when the infections were severe indicates that deep-seated tissues were involved.

MATERIALS AND METHODS

I have studied especially the production of intumescences on woody stems of *Pyrus malus* (apple, variety Transparent) and made a few general experiments on apple (variety Williams) and *Populus deltoides*. Branches from 1 to 1.5 cm. in diameter at the base were cut from trees growing out of doors. These shoots were then cut into short lengths (10–15 cm. long) and the latter were grouped into sets, each of which included a graded series of sizes from 1.5 cm. in diameter down to slender terminal twigs. I shall call such pieces cuttings. There was some variation in the number of cuttings to a set in the different experiments; but the number was never less than five nor more than twenty. The results reported in my first paper were obtained during the winter period from September to March. The work has now been extended over the entire year.

The oxygen and nitrogen used were obtained from the Linde Air Products Company and were from 98 to 99 per cent pure. The ethylene was of the quality sold by the Industrial Alcohol Company for use as an anaesthetic, and it proved to be of very high grade, from 97 to 99 per cent being absorbed by bromine water. The carbon dioxide was of the type used for preparing carbonated beverages, 99 per cent being absorbed by potassium hydroxide.

As gas chambers for the cuttings, I at first used twenty-liter bell-jars inverted in shallow pots full of sand. One and one-half liters of quartz sand were poured into each jar and water was added until the moisture content was about the same as that commonly used for rooting cuttings. The jars were closed with ground-glass plates on their tops. The condensation of water vapor inside the jar usually maintained a water seal between the ground-glass plate and the rim of the jar. The volume of ethylene required to make the concentration desired for a test was collected in a suitable vessel, such as a glass tumbler or a battery-jar, by water displacement in a pneumatic trough. The vessel was then closed by a glass plate of suitable size, and the vessel with its cover was removed from the trough and placed in the experimental jar with the cuttings. After the ground-glass plate had been put in place over the mouth of the bell-jar, the gas was liberated by pulling a small cord which had previously been attached to the cover of the enclosed vessel. In all experiments the pieces of stems were placed with the basal end downward in contact with moist sand or filter paper as if for rooting experiments.

To obtain gas mixtures of more accurately known composition for testing the extremely low concentrations as reported, the apparatus described above was modified in several details. The ground-glass surfaces of the glass plate and the rim of the bell-jar were coated with castor oil, and a heavy weight was placed on the plate after it had been put in place. This modification reduced the chances of any possible interchange of gases between the interior of the bell-jar and the surrounding atmosphere. All quantities of ethylene or mixtures of ethylene and air which were used to make the desired concentrations were introduced into the bell-jars by means of a gas burette and mercury leveling bulb, through tubulations in the bell-jars. The tubulations were supplied with ground-glass stopcocks. It was found convenient to use ethylene-air dilutions in making the low concentrations. These were made in the following manner: Tubes supplied with ground-glass stopcocks were sealed into the mouths of twelve-liter bottles. A 120 cc. sample of ethylene was then forced into the first bottle by means of the gas burette and mercury leveling bulb, thus forming in the bottle a mixture composed of 1 per cent of ethylene and 99 per cent air, by volume. After a twenty-four hour period a 120 cc. sample of this ethylene-air mixture was withdrawn and added to a second bottle, thus forming a concentration of approximately 1 part of ethylene to 10,000 parts of air.[1] After a further equal interval of time a similar volume was drawn from this bottle and added to a third bottle, thus forming a dilution of 1 part of ethylene to 1,000,000 parts of air. These three supply bottles were then used to make the dilutions desired in the twenty-liter bell-jars in which the cuttings were exposed to the gas. For example, the addition of 200 cc. of the gas mixture from one of these bottles to a twenty-liter bell-jar formed a concentration in this jar which was one-hundredth as great as was present in the bottle from which the sample was drawn. Concentrations greater than 1 part of ethylene to 10,000 parts of air were made directly with pure ethylene by means of the mercury leveling bulb and the gas burette.

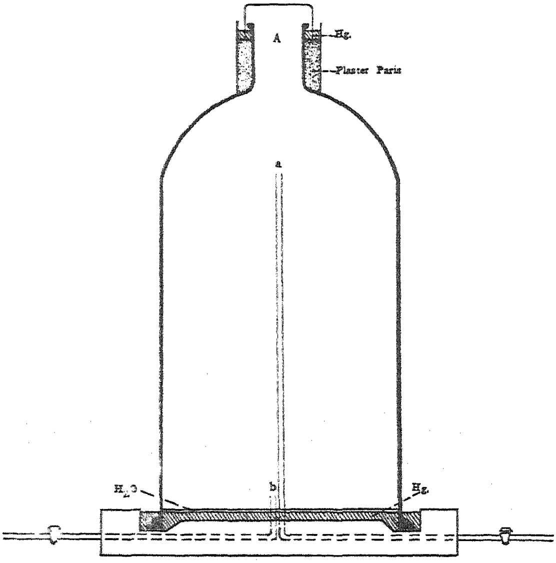

Fig. 1. Optical section of twenty-liter bell-jar and cement base used as experimental chamber for controlling the composition and rate of flow of gas mixtures supplied to the cuttings. (For full explanations see text.)

Hermetically sealed experimental chambers were used in some of the experiments. One type of these consisted of four-liter bottles supplied with large ground-glass stoppers. The bottles were calibrated approximately by pouring into them given volumes of water and marking the levels on the side of the bottle with a wax pencil. The bottles were then filled with water and the experimental materials were placed inside, after which the bottles were inverted in a pneumatic trough and the required volumes of the desired gases added by water displacement. The ground-glass stoppers were put in the bottles and sealed in place with sealing wax. This type of chamber was used only when the series of concentrations varied by increments of twenty-five per cent or more.

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[1] It should actually be 1 part of ethylene to 9,999 parts of air, but the difference is of course negligible and within the experimental error. For convenience of reference, this sort of difference will be disregarded in the descriptions and discussions which follow.

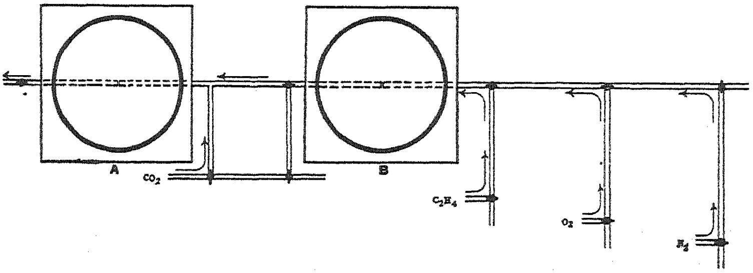

Fig. 2. Ground plan of cement bases, A and B, showing the arrangement of three-way stopcocks and glass tubes which make possible the addition or removal of known volumes of gases from any part of the system. The arrangement is figured as adjusted for experiments on exposure time, when cuttings in jar B were exposed to a mixture of ethylene, oxygen, and nitrogen in the absence of carbon dioxide, while those in jar A were exposed to the same gas mixture as in B with the addition of sufficient carbon dioxide to form a concentration of 10 per cent of the total gas volume.

It seemed desirable during the progress of this study to devise and construct an apparatus which would enable one not only to control the initial percentage composition of the experimental mixtures, but also to maintain this composition continuously by flowing the desired gases through the system. To meet these requirements an apparatus was constructed whereby gas mixtures of any desired composition or rate of flow could be passed continuously through hermetically sealed exposure chambers. The type of chambers used in this work was constructed as shown in figure 1. A base of cement, 40 cm. square and 8 cm. thick, was constructed with a groove in its upper surface which would just receive the rim of a twenty-liter bell-jar. Inlet *a* and outlet *b* were embedded in the base at the time it was poured. The vertical portions of these delivery tubes were made of tin, since it was found to be nearly impossible to avoid breaking glass ones when removing or replacing the bell-jars. The bell-jar was placed upright on this base with its rim fitting into the groove, and a quantity of mercury sufficient to form a hermetical seal from 1–1.5 cm. deep was poured into the groove. Water was then added, so that a layer about .5 cm. deep covered the mercury. This was done to obviate possible toxic effects of mercury vapor. In some cases the bell-jars were tubulated at the top, which made possible the construction of the sealed opening (shown in detail at A in figure 1) that allows one to add or remove small objects without lifting the bell-jar from its base. Four chambers of the kind just described were connected in series, as shown in figure 2. The arrangement of glass tubes and three-way stopcocks allows one to add or remove volumes of gas at will from various parts of the system. All joints, whether glass to glass or tin to cement, were made with De Kotinsky's cement.

The gas mixtures which were passed through these enclosure chambers were controlled by either one of two methods. In the first method air was drawn or blown through the system by means of a vacuum-pressure pump which was connected to a water faucet. The water system used to run this pump was supplied with a constant-pressure reducing valve, next to the pump itself, in order to insure a more nearly constant rate of flow. This pump, as it normally functioned, drew about twice as much air through the vacuum side as it forced out of the pressure side, the other half being used in the pump in the formation of the pressure force. The rate of flow was maintained within about 10 per cent of the desired amount by regulation of the water pressure by the reducing valve, and by adjusting the pump itself.

The second method used for controlling the gas mixtures flowing through the chambers was by the use of the cylinders of compressed gases mentioned above. The cylinders were supplied with constant-pressure reducing valves which were connected with the inlets of the system of chambers (figure 2). It was possible to obtain a wide range of rates of flow from the cylinders by adjusting the relation between the size of the orifice of the valve and the gas pressure back of it. The rates of flow were checked by determining, with a stopwatch, the length of time required to fill a gas burette or pipette with the gas. This same method was used at intervals to test the constancy of the rate of flow.

Adjustment of the relation between the size of the orifice and the pressure of the gas in the reducing valve controlled both the percentage composition and the rate of flow of the experimental gas mixtures through the chamber. Thus if the time periods required for 100 cc. of the gas to be liberated from the nitrogen and oxygen cylinders were, respectively, 45 seconds and 180 seconds, the resultant percentage composition of the experimental atmosphere would be 20 per cent of oxygen and 80 per cent nitrogen, while the rate of flow of these combined gases through the chamber would be 10 liters per hour.

Tests were made to determine the accuracy of this apparatus. These tests were made volumetrically by determining with a stopwatch the time required for a given volume of gas to be liberated into the system from each of the cylinders. In table 1 is given a representative set of such readings covering a period of six days during which an experiment was being made; the apparatus was not adjusted during that time. It is apparent from an examination of the data that the rate of flow of each gas was maintained with a range of variation not exceeding one-tenth of the desired concentration. An analysis with an Orsat apparatus of the experimental atmosphere as it came from the exposure chambers showed a similar degree of accuracy of control.

TABLE I

Stopwatch readings in seconds for period of six days of rate of flow of the four gases passing through the apparatus

KIND OF GAS	SIZE OF SAMPLE	TIME REQUIRED FOR LIBERATION OF SAMPLE					
		1st day	2nd day	3rd day	4th day	5th day	6th day
Nitrogen	100 cc.	45	44.9	46.2	46.5	47.2	49.
Oxygen	100 cc.	180	183	187	187	187	188
Carbon dioxide	100 cc.	361	375	365	369	385	385
Ethylene	10 cc.	542	570	595	566	566	568

DESCRIPTION OF RESULTS

The general character of the intumescences

It is obvious from a review of the literature as given above that various pathological outgrowths on roots, stems, and leaves which consist chiefly of hypertrophy of the affected tissues have been termed "intumescences." More careful cytological and experimental studies of these outgrowths may make possible a more adequate classification of them. The proposal of Küster (1903) to limit the term intumescence to small pustule-like overgrowths is apparently not based on any other than artificial considerations of convenience. Both Sorauer (1886) and Küster (1903) have used the term to include a wide range of overgrowths varying as to the relative degree of hyperplasia and hypertrophy involved, the characters of the tissues produced, and the stimuli which lead to their development. Küster (1903) notes that such "intumescences" do not differ in their method of development from the more extensive lenticel overgrowths for which he used the term excrescence.

As I reported in my preliminary paper, when conditions are favorable intumescences due to ethylene stimulation may appear in the buds, in the proximal or distal ends, and in the internodal regions of stem cuttings of Transparent apple (see Wallace, 1926, plates 14 and 15, fig. 1–11). As a rule the buds first show intumescences. The reaction appears first on the surface as a transverse breaking of the epidermis and cork layers on each side of a bud base. The time required for the appearance of this response may be as short as forty-eight hours or as long as six days. Four days, however, is usually sufficient to bring about the response. Proliferation and maceration of the cells of the bud and bud base may proceed rapidly, and within a few days the entire resting bud containing the leaf primordia for the following year may be resolved into a loose mass of rounded cells. Externally the buds in this condition present an appearance very suggestive of popped corn. The curled remnants of bud scales, cork layers, etc., adhere to the enlarging tissues beneath. This swollen, white tissue is so friable that a slight jar often suffices to cause most of the intumescence to fall from the stem. This may, in some cases, result in the exposure of tissue as deep-seated as the xylem of the stem. Not infrequently such an intumescence may occur in the region of the bud-scale scars which mark the position of the terminal buds of previous years.

Intumescences in the distal ends of the cuttings begin before the bud intumescences have reached their complete development (that is, in from five to eight days after exposure to the gas), and their development is similar to that described for buds. The first evidence of intense responses, in the case of twigs cut off at both the basal and the apical ends, is a swelling that produces a longitudinal rupturing of the epidermis and cork layers near the apical end. Swellings of this kind may extend back from the tips of the cuttings for 2–3 cm. in some cases. Proliferation and swelling then proceed as in the region of the buds, but the disorganization of the tissues is never so complete. Frequently, most of the cell enlargement is limited to the deeper regions of the cortex, with the result that a layer composed of the outer layers of the phloem and cortex, containing the chlorenchyma, is split off and raised upon a pad of loose parenchyma. In all cases, the chlorenchyma layer retains its green color, though it may be torn so as to expose rifts or lesions lined by light colored, hypertrophied cells. The zone of transition between the swollen region of the tip and the normal regions below is generally rather sharp. Two or even three sharply delineated bands of swollen tissue similar to those which form in the region of the tips may be present on one cutting, distributed at irregular intervals along its length. The tissues lying between these swollen zones are apparently normal. The increase in the diameter of the stem in the region of a swollen zone usually varies directly with the width of the zone. Swollen zones that are very narrow may raise the bark only 1 mm. or less, while those which are 2 cm. or more in width may completely rupture the epidermis and cork layers and increase the diameter of a twig whose normal diameter is only 4 mm. to as much as 6–8 mm.

Intumescences in the internodal regions occur later than those in the ends and appear in from nine to twelve days after exposure to the gas; they reach their maximum development five to ten days later. These swellings may be relatively superficial, or they may form deep-seated cankers that penetrate to the xylem by long, deep, longitudinal rifts that run the entire length of the cutting. In a superficial type of response (plate 34 figure 1), the phellogen proliferates so as to produce a splitting and rolling back of the cork, thus exposing extensive areas of the chlorenchyma. Examination of the surface of the chlorenchyma of a cutting of this kind shows it to be made up of large, globular, hypertrophied cells. Other cuttings may show, in addition to proliferation of the phellogen and hypertrophy of the chlorenchyma, one or more longitudinal rifts which penetrate into the deeper layers of the bark. The most deepseated type of intumescence is well shown in plate 34, figure 2. Here the disorganization of the tissues in certain areas is almost as complete as that found in the proliferated buds. In general the cuttings which I have studied were affected about equally throughout their entire length, but in some cases there seemed to be a tendency for the lower portions to react less strongly or not at all. Usually in cases where an internodal swelling is situated below a terminal swelling on the same cutting, the two tend to run together.

The formation of intumescences successively in the buds, in the internodal, and in the distal regions seems to be the typical response of the cuttings of Transparent apple to stimulation by ethylene gas.[2]

Populus deltoides, when exposed to ethylene gas, forms intumescences at the base of the buds or in the internodes, but no swellings have been observed at the cut ends.[3] The internodal responses are rarely conspicuous and frequently may not occur at all, but large intumescences generally appear at the base of the buds. The response usually begins within about five days after the cuttings have been exposed to the gas. Proliferation at the base of the buds gives rise to a pad of soft, white tissue that completely separates the bud from the stem, though, in contrast with the case of apple, the leaf primordia usually remain intact. The cells of this mass of tissue are long and sac-like and cling together to form a delicate cotton-like mass; they are not loose and granular like those in the buds of apple. At the end of a week such an intumescence may be 1 mm. in diameter. By the end of a month it may be as much as 1 cm. long by 0.8 cm. wide and 0.5 cm. thick (Plate 34, figures 3, 4, and 5). I have not determined the maximum size which such an outgrowth may attain.

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[2] Three varieties of apple which I have studied indicate that there may be a great varietal variation in the capacity to form these outgrowths. Transparent has always shown the greatest capacity for response. A large tree, of unknown variety, formed intumescences in the three regions, but they were never strong, and were often lacking. A third variety, Williams, never formed an intumescence in the buds or in the internodes, but did form strong intumescences in the distal ends.

[3] These intumescences have formed equally well in concentrations of 1 per cent ethylene and 1 part of ethylene to 10,000 parts of air.

The hypertrophied cells which make up the greater part of these intumescences in apple are snow-white in mass, but are almost devoid of color when viewed as individual units. They vary from globular to ovoid or sometimes almost filamentous in form. The cell walls are always extremely thin. The nuclei appear normal, but the plastids aggregate in a thickened band of the primordial utricle around the equator of the cell. Typically the plastids are arranged in one such band, but not infrequently a single cell may contain two or even three bands placed at irregular intervals between the two extremities of the cell, but not necessarily parallel to each other. Starch grains, which are very conspicuous in the plastids of the hypertrophied cells at the time of their formation, gradually disappear as the cells grow older, so that none are present after three or four weeks. The cells then die and turn brown, apparently through exhaustion of their food reserves.

My experiments show that the intumescences of apple cuttings described above may form under a wide range of environmental conditions. They were obtained in stems ranging in age from young succulent growths of the current year to stems as much as twelve years old.[4] Likewise, cuttings which have been kept as controls for a month have later given the response after being exposed to the gas. Preliminary experiments indicate that acetylene, the next member of the unsaturated hydrocarbon series, may induce a similar type of response.

The following experiments were made, unless stated to the contrary, on cuttings of Transparent apple. The pieces used were 10–15 cm. long and of graded sizes from 1.5 cm. in diameter down to slender terminal twigs. The data recorded in the tables represent the maximum response which the cuttings showed under the conditions of the experiment. The length of time required for maximum development of the intumescences varied from about a week for those at the base of buds to two or more weeks for those at the ends of the cuttings and in the internodes. The degree of development of these swellings is recorded in the tables as: none, weak, medium, strong, and maximum. I report no special experiments on the effect of light because from the very first it was evident that the reactions took place equally well whether in complete darkness, in continuous light, or in alternate light and darkness.

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[4] Intumescences similar to those formed in the internodes of the stems have been formed on the large and small (1 cm.–5 cm.) roots collected from the same trees. These roots were probably of some other variety than Transparent since the trees were grafted stock.

TABLE 2

Response to ethylene in different branches from the same tree[1]

BRANCH NO.	POSITION OF BRANCH	NO. OF PIECES	LOCATION OF INTUMESCENCES					
			Internodes		Distal ends		Buds	
			Degree	No.	Degree	No.	Degree	No.
1	Top of the tree	8	strong	7	weak	6	medium	6
2	Second from top	8	control		none		none	
3	Third from top	8	maximum	8	weak	7	medium	17
4	Fourth from top	8	strong	6	medium	6	medium	8
5	Middle of tree	8	maximum	8	weak	3	medium	8
6	Middle of tree	8	strong	7	medium	7	medium	8
7	Middle of tree	8	strong	8	medium	7	medium	8
8	Base of the tree	8	strong	8	medium	7	medium	14

[1] The character of the responses is graded as follows: none, weak, medium, strong, and maximum. The numbers given for the internodal and apical responses refer to the number of cuttings showing the response; those for the bud responses refer to the number of buds reacting and not to the number of stems on which the buds were borne.

Tests begun July 14; concentration of ethylene, 1 part to 40 parts of air; exposure time, 48 hours.

General preliminary experiments

Experiments made on branches taken from various parts of the same tree showed no significant variation in the sensitiveness of different branches to stimulation by ethylene gas. Eight branches were collected at one time from different parts of the same tree and cut into eight cuttings each. These sets were then placed in 15-liter bell-jars (one set to a jar), and a volume of ethylene sufficient to produce a concentration of 1 part of ethylene to 40 parts of air was liberated into each bell-jar by removing the cover from a small vessel containing ethylene which had been inclosed in the large bell-jar, as described above.

TABLE 3

Response to ethylene in branches from different trees of the same variety of apple[1]

TEST NO.	DATE	NO. OF TREE	NO. OF PIECES	LOCATION OF INTUMESCENCES						ABSCISSION OF LEAVES	
				Internodes		Distal ends		Buds			
				Degree	No.	Degree	No.	Degree	No.	Degree	No.
1	July 18	1	8	weak	5					complete	2
		2	8	none						complete	2
		3	8	weak	6					complete	1
		4	8	weak	1					partial	
		5	8	weak	2					partial	
		6	8	none						partial	
		7	8	none						partial	
		8	8	none						partial	
2	July 21	1	8	medium	1	medium	3	weak	4	complete	5
		2	8	medium	1	medium	3	medium	2	complete	7
		3	8	none		weak	2	none		complete	5
		4	8	weak	2	medium	3	none		complete	7
		5	8	weak	1	weak	1	none		complete	7
		6	8	weak	1	medium	2	medium	3	complete	4
		7	8	weak	1	none		none		complete	7
		8	8	medium	1	medium	2	medium	2	complete	5
3	July 27	1	8	strong	4	medium	4	medium	4	partial	
		2	8	strong	4	medium	4	medium	3	complete	6
		3	8	none		strong	5	weak	2	complete	3
		4	8	strong	8	strong	8	strong	10	complete	8
		5	8	none		medium	3	none		partial	
		6	8	weak	3	medium	4	none		complete	8
		7	8	medium	3	medium	7	strong	3	complete	8
		8	8	weak	2	medium	4	medium	5	complete	8

[1] Tests 1 and 2 were made on cuttings from the same eight trees, while test 3 was made from cuttings from eight other trees of the same variety. The degree of abscission of leaves is designated as partial when only part of the leaves fell from a stem, and complete when all fell.

Concentration of ethylene, 1 part to 40 of air; exposure time, 48 hours.

The jars were then left closed for forty-eight hours, after which the ground-glass plates were removed for a like period of time and then replaced. The jars then remained closed for the remainder of the experiment except during the brief periods in which readings were being made. Cuttings from every branch, whether from the top or the base of the tree, developed intumescences in the buds and internodes and at the distal ends (table 2).

Similar experiments with branches taken from eight different trees of Transparent failed to show a variation great enough to indicate any essential difference in their susceptibility. The variation in the number of pieces showing intumescences and the degree of the response, as shown in table 3, were of the same order of magnitude as the variations in pieces from the same branch.

TABLE 4

Response to ethylene in cuttings collected at different times of the year[1]

TEST NO.	DATE	NO. OF PIECES	LOCATION OF INTUMESCENCES					
			Internodes		Distal ends		Buds	
			Degree	No	Degree	No.	Degree	No.
1	Oct. 29	6	medium	4	medium	4	none	
2	Nov. 10	12	none		strong	12	none	
3	Nov. 16	10	none		medium	9	medium	3
4	Nov. 24	8	none		medium	7	none	
5	Dec. 21	15	none		none		none	
6	Jan. 1	15	maximum	15	maximum	15	maximum	15
7	Jan. 5	15	medium	15	medium	15	medium	2
8	Jan. 18	15	none		none		none	
9	Feb. 1	5	none		weak	1	weak	1
10	Feb. 7	5	none		none		none	
11	Feb. 14	5	medium	4	medium	4	medium	3
12	Feb. 23	5	none		medium	2	none	
13	Mar. 9	5	none		none		none	
14	Mar. 22	5	none		none		none	
15	Mar. 29	5	weak	1	none		none	
16	Apr. 4	5	medium	1	none		medium	3
17	Apr. 12	5	weak	4	none		none	
18	Apr. 21	5	weak	4	none		none	
19	Apr. 30	5	none		medium	1	weak	2
20	May 12	5	none		none		none	
21	June 3	5	none		weak	3	none	

[1] Concentration of ethylene, 1 part to 200 parts of air; exposure time, varied,—usually 48 hours.

I reported in my preliminary paper that such intumescences could be produced during the fall and winter period from September to March, and I can now report like results for the entire year. In table 4 are given the results for a series of tests extending from October, 1925, to June, 1926. As will be seen from the table there was great variability in the results of these experiments during this period. In another series treatments of new lots of cuttings were started four times daily for a period of twelve days. The results given in table 5 for this short interval show the same irregularities as those shown in table 4 for similar experiments extending over a period of eight months. These two series indicate that the irregularities in the responses secured were not due to differences in the internal condition of the twigs that might have been correlated with their seasonal condition when collected. These experiments were made under

TABLE 5

Response to ethylene in cuttings made four times daily for twelve days[1]

TEST NO.	TIME[2]		NO. OF PIECES	LOCATION OF INTUMESCENCES					
				Internodes		Distal ends		Buds	
	Day	Hour		Degree	No.	Degree	No.	Degree	No.
1	7	12 n.	6	maximum	4	medium	4	weak	3
2	7	6 p.m.	7	medium	2	medium	6	weak	2
3	7	12 m.	8	medium	4	medium	6	weak	3
4	8	8 a.m.	5	weak	3	medium	4	weak	4
5	8	12 n.	8	medium	3	medium	7	medium	4
6	8	6 p.m.	7	medium	4	medium	5	medium	5
7	8	12 m.	11	strong	6	weak	6	medium	4
8	9	8 a.m.	7	weak	2	weak	5	medium	15
9	9	12 n.	10	weak	7	weak	5	medium	7
10	9	6 p.m.	7	weak	2	medium	4	none	
11	9	12 m.	9	weak	2	weak	3	weak	1
12	10	8 a.m.	6	weak	1	medium	2	weak	1
13	10	12 n.	11	medium	4	weak	6	weak	2
14	10	6 p.m.	9	weak	7	medium	5	weak	1
15	10	12 m.	12	medium	7	weak	6	medium	9
16	11	8 a.m.	7	medium	4	weak	4	medium	6
17	11	12 n.	10	weak	6	strong	7	medium	4
18	11	6 p.m.	10	medium	3	medium	2	weak	1
19	11	12 m.	11	weak	1	weak	1	weak	2
20	12	8 a.m.	6	weak	1	weak	2	none	
21	12	12 n.	9	weak	3	none		none	

TABLE 5—*Continued*

TEST NO.	TIME [2]		NO. OF PIECES	LOCATION OF INTUMESCENCES					
				Internodes		Distal ends		Buds	
	day	Hour		Degree	No.	Degree	No.	Degree	No.
22	12	6 p.m.	10	weak	2	weak	2	none	
23	12	12 m.	12	weak	3	weak	1	none	
24	13	8 a.m.	0						
25	13	12 n.	12	weak	1	none		none	
26	13	6 p.m.	11	none		none		strong	1
27	13	12 m.	9	none		weak	4	none	
28	14	8 a.m.	6	none		medium	1	none	
29	14	12 n.	10	none		weak	1	none	
30	14	6 p.m.	12	none		weak	2	none	
31	14	12 m.	11	none		weak	1	none	
32	15	8 a.m.	5	none		medium	2	none	
33	15	12 n.	9	none		none		none	
34	15	6 p.m.	11	none		none		none	
35	15	12 m.	9	none		none		none	
36	16	8 a.m.	11	weak	2	strong	1	medium	11
37	16	12 n.	8	maximum	7	weak	2	maximum	35
38	16	6 p.m.	6	medium	5	weak	4	medium	11
39	16	12 m.	6	weak	4	medium	4	weak	5
40	17	8 a.m.	6	weak	3	weak	2	weak	1
41	17	12 n.	6	weak	3	none		none	
42	17	6 p.m.	6	none		none		none	
43	17	12 m.	6	none		none		none	
44	18	8 a.m.	6	weak	3	weak	3	medium	6
45	18	12 n.	6	none		none		none	
46	18	6 p.m.	6	none		none		none	
47	18	12 m.	7	none		none		none	
48	19	8 a.m.	8	none		none		none	

[1] Concentration of ethylene, 1 part to 40 of air; exposure time, 48 hours.

[2] The tests were made during June, 1926; the calendar days of the month are shown. Noon is denoted by n., midnight by m.

greenhouse conditions. The temperature fluctuated through a range from 15° to 40° C. Special experiments planned to test the influence of temperature indicate that high temperatures were probably responsible for the failure to get responses in certain cases given in tables 4 and 5. In the experiments conducted from June, 1926, to March, 1927, care was taken to avoid excessively high or low temperatures, and consistant responses were obtained in every test of the entire series.

Effect of varying environmental conditions on the response to ethylene

Relation of humidity to response. Varying degrees of atmospheric moisture, within the range studied, were found to have little or no influence upon the reaction of apple twigs to ethylene. The humidity was controlled in a series of hermetically sealed bell-jars, as described above. Two of the bell-jars were connected to the vacuum side and two to the pressure side of the vacuum-pressure pump. In this manner air could be drawn through the first two bell-jars at a rate of about 40 liters per hour and then passed through the pump and forced back through the other two bell-jars at a rate of about 20 liters per hour. Calcium chloride tubes were arranged between the bell-jars so as to maintain relative humidities of 67, 75, 84, 88, and 92 per cent. Actual tests of the relative humidity of the air in each chamber were made three times daily with a wet and dry bulb hygrometer (hygrodeik), and the average values of these readings for the period of seven days during which the experiment was continued are recorded in table 6. The five sets of cuttings were exposed to 1 part of ethylene to 100 of air for twelve hours prior to being transferred to the bell-jars with controlled humidity. The gas mixture in the exposure chamber was made up of volume proportions of 1 part of ethylene, to 20 parts of oxygen, to 80 parts of nitrogen, in addition to the water vapor needed to give the desired humidity; and these proportions were maintained during the period of exposure to

TABLE 6

Relation of humidity to the formation of intumescences[1]

RELATIVE HUMIDITY	NO. OF PIECES	INTUMESCENCES IN THE DISTAL ENDS	
		Degree	No.
per cent			
67	10	weak	9
75	10	strong	5
84	10	medium	6
88	10	maximum	8
92	10	strong	8

[1] Tests begun Oct. 25: Concentration of ethylene, 1 part to 100 of air; exposure time, 12 hours.

the ethylene by regulating the rate of liberation of the three gases from cylinders by means of pressure-reducing valves, as described above. The basal end of each cutting was in contact with either moist sand or moistened filter paper, as in all the other experiments. The temperature, and hence the water vapor pressure deficit, remained nearly constant during the experiment. As shown in table 6, intumescences formed on cuttings in all the gas chambers. With a humidity of 67 per cent the response was weak, but nine out of ten cuttings reacted. In the jar with a humidity of 84 per cent the intumescences were fairly well developed, but occurred on only six of the ten cuttings. Strong responses occurred on five cuttings in the jar with a humidity of 75 per cent, and on eight cuttings in the jar with a humidity of 92 per cent. It would seem, therefore, that relative humidity within the range of 67–92 per cent had little or no influence on the response.

Relation of temperature to response. Experiments made with temperatures ranging from about 15° C. to 30° C. showed definite effects on the degree of the response, but neither extreme exceeded the range in which intumescences may form. Four twelve-liter bell-jars were placed so as to maintain various temperatures. One container was put on a laboratory table where the room temperature was about 20° C. Another was placed in an ice-box with a temperature of about 15° C. The temperature values given in table 7 for these two jars are the averages of their readings for the period of the experiment. The other two containers were kept in electric incubators adjusted to maintain temperatures of 25° and 30° C., respectively. These containers were filled with 1 per cent of ethylene and 99 per cent air, and sets of 8–14 cuttings were placed in each. Some intumescences developed at each temperature, but there were pronounced differences in the intensity of the responses at the different temperatures. In these tests no internodal swelling formed on any of the twenty-nine cuttings kept at 30° C. Weak to medium terminal intumescences developed on 12 of them. At 25° C. weak to medium internodal swellings formed on sixteen cuttings out of twenty-nine, while twenty of the twenty-nine showed medium responses at their distal ends. Responses at room temperatures (19–20.5° C.) were much stronger than those at the two higher temperatures; since medium to weak terminal

TABLE 7

Relation of temperature to the formation of intumescences[1]

TEST NO.	DATE	AVERAGE TEMPERATURE C.	NO. OF PIECES	LOCATION OF INTUMESCENCES			
				Internodes		Distal ends	
				Degree	No.	Degree	No.
1	Nov. 24	15.0	13	maximum	12	maximum	12
		20.5	14	medium	12	medium	12
		25.0	13	medium	10	medium	10
		30.0	12	none		weak	8
2	Dec. 1	15.0	8	strong	7	strong	7
		19.0	8	medium	4	medium	4
		25.0	8	weak	6	medium	6
		30.0	8	none		medium	1
3	Dec. 8	14.8	8	maximum	7	maximum	7
		19.5	8	weak	6	weak	6
		25.0	8	none		medium	6
		30.0	8	none		weak	3

[1] Concentration of ethylene, 1 part to 100 parts air; exposure time, throughout the experiment.

and internodal swellings formed on twenty-two out of the thirty cuttings. The most pronounced responses were obtained at 15° C., the lowest temperature of the entire series. These intumescences were among the best developed that I have had. They involved almost the entire length of the cuttings and showed deep rifts and high ridges of proliferated tissue. Also, as will be observed from table 7, the percentage of cuttings responding at 15° C. was very high, only three of the twenty-nine failing to develop intumescences.

Conditions affecting penetration by the gas. My experiments have shown apparently that many buds of Transparent apple may fail to form intumescences because the ethylene has not penetrated into them. Usually only one bud in ten to fifteen gives a response after the cuttings have been exposed to ethylene. I have been able, however, to obtain responses in about 90 per cent of the buds by cutting away a portion of the thickened, corky leaf-scar at the base of each bud. Table 8 gives the results obtained in a representative experiment. Only three buds out of a total of fifty-nine developed intumescences when

TABLE 8

Effect on intumescence formation of removal of the abscission layer at base of buds[1]

CUTTING NO.	ABSCISSION LAYER NOT REMOVED		ABSCISSION LAYER REMOVED	
	No. of buds	No. of responses	No. of buds	No. of responses
1	5	1	2	1
2	3	0	2	2
3	2	0	1	1
4	3	0	6	6
5	5	1	2	2
6	3	0	10	10
7	3	0	3	3
8	6	0	8	8
9	9	0	3	1
10	6	0	2	2
11	4	1	2	2
12	7	0	2	2
13	3	0	5	4
14			4	3
15			6	6
Totals	59	3	58	53

[1] Concentration of ethylene, 1 part to 100 of air; exposure time, throughout the experiment.

the corky layers were not removed, while of fifty-eight other buds from whose bases the corky layers were removed, only 5 failed to respond. Moreover, after the layers had been removed from thirty-two of the buds mentioned above which had failed to respond to ethylene, all but 5 gave responses. However, this removal of the corky layer did not always assure a response and in some cases nearly every bud on a cutting has given a response without removal of the corky layers. Like attempts to induce responses in the buds of Williams, a variety which has never given bud responses, by cutting the base of the buds proved unsuccessful.

In order to study the influence of facilitating the access of the ethylene to the tissues, the corky layers of the bark were removed in some of the tests. This treatment did not always result in more extensive intumescences than those produced on cuttings with uninjured bark. Pieces of the living bark that were stripped from the stems and exposed to ethylene showed little or no proliferation. Further study will be required before definite statements can be made as to the part that lenticels and various types of wounds may play in affecting the absorption of ethylene by twigs.

Dosage effects. The most striking fact regarding the formation of these intumescences on the stems of Transparent apple is perhaps the constancy of the results under extreme ranges of concentration of the gas. Mixtures composed of 75 per cent of ethylene and 25 per cent of oxygen give about the same response as others made up of 1 part of ethylene to 10,000 parts of air. There is an apparent decrease in the intensity of the response when the concentration is changed from 1 part of ethylene and 10,000 parts of air, to 1 part of ethylene and 1,000,000 parts of air. Still, definite intumescences have formed on the distal ends of apple cuttings when treated with dilutions of 1 part to 1,000,000, and 1 part to 100,000,000. The reactions in these two last concentrations are always weak and are slower in making their appearance, but they are distinct.

Numerous experiments have shown that intumescences may form on the stems of Transparent apple in response to extremely low concentrations of ethylene gas. Thus, as shown in test 1 table 9, a series of concentrations ranging from 75 per cent ethylene and 25 per cent oxygen, to 1 part of ethylene to 10,000 parts of air gave well developed intumescences. Within this range of concentrations the intensity of the response seems to bear little or no relation to the gas concentration, as is shown by both qualitative and quantitative measurements of the reaction. An examination of the data of the five tests likewise indicates that there was no significant decrease in the intensity of the response when the concentration of ethylene was reduced from 1 per cent to 1 part of ethylene to 10,000 parts of air. However, a further decrease in the concentration, from 1 part to 10,000 to 1 part to 1,000,000 or 100,000,000, showed a definite decrease in the intensity of response. The intumescences formed in these last two concentrations were always on the ends of the cuttings and usually extended back from the tips only a few millimeters, but they were always distinct.

The interval of time necessary for the appearance of the responses was directly proportional to the concentration of

TABLE 9

Relation of extreme ranges of concentrations of ethylene to the formation of intumescences[1]

TEST NO.	DATE	NO. OF PIECES	COMPOSITION OF MIXTURE		COMBINED INTUMESCENCES IN INTERNODES AND DISTAL ENDS		
			Air	Ethylene	Qualitative		Quantitative Av. length in cm.
					Degree	No.	
1	Nov. 15	8	25[2]	75	maximum	5	15.0
		7	75	25	maximum	6	12.0
		6	100	1	maximum	6	8.5
		7	10,000	1	maximum	6	16.0
2	Nov. 19	13	100	1	maximum	13	15.4
		11	10,000	1	maximum	10	13.0
		11	1,000,000	1	medium	10	5.9
		11	100,000,000	1	weak	9	4.1
3	Dec. 1	8	100	1	medium	5	
		8	10,000	1	medium	7	
		8	1,000,000	1	weak	4	
		8	100,000,000	1	weak	4	
4	Feb. 14	10	100	1	maximum	9	7.7
		10	10,000	1	maximum	9	6.5
		10	1,000,000	1	weak	3	.5
		10	100,000,000	1	weak	2	.2
		10	control	0	none		
5	Mar. 15	10	100	1	strong	5	3.2
		10	10,000	1	strong	3	4.8
		10	1,000,000	1	medium	5	.9
		10	100,000,000	1	medium	3	.6
		10	control	0	none		

[1] Exposure time: test 1, 72 hours; tests 2 and 3, 1 week; tests 4 and 5, two weeks.

[2] This one combination was oxygen-ethylene, only; all others were ethylene-air, as shown.

ethylene, in these tests with series of concentrations from 1 per cent to 1 part to 100,000,000. The terminal responses usually appeared after three to four days in the highest concentration. The responses in the other concentrations then followed at intervals of 24 to 48 hours, following the descending series of concentrations. Thus, it was usually about a week before any response was evident in the mixture of 1 part of ethylene to 100,000,000 parts of air.

The methods of controlling the ethylene concentration and of conducting the experiments were varied in order to insure accuracy in the composition of the mixture and to check the constancy of the results. The gas chambers for tests 1, 2, and 3 (table 9) were twenty-liter bell-jars, hermetically sealed, in the manner described above, by means of cement bases and mercury. Those for tests 4 and 5 were similar jars inverted and sealed by means of ground-glass plates and castor oil. Gas mixtures in which the concentration of ethylene was greater than 1 per cent were made by flowing the ethylene and other gases through the jars in the required proportions during the entire exposure period for the experiment. All concentrations of ethylene from 1 per cent to 1 part to 100,000,000 of air were made with the gas burette and leveling bulb, as described. The concentrations were made in an ascending series in order that the amount of ethylene which might remain in the burette, when changing from one concentration to the next higher, would be insignificant when compared with the amount in the mixture of higher concentration being made. Exposure periods were seventy-two hours for test one, one week for tests two and three, and two weeks for tests four and five. In no case was there renewal of the gas mixture inside a chamber during the period of a test.

Relative effects of illuminating gas and ethylene. Ethylene and illuminating gas have given about the same responses over a wide range of concentrations. Sets of cuttings were placed in twenty-liter bell-jars containing air and quantities of ethylene sufficient to form concentrations of 0.05, 0.5, 5, 25, 50, and 100 per cent (table 10). Similar preparations were made with illuminating gas and air so as to obtain parallel series of concentrations of the two gases. The jars containing 100 per cent of ethylene or illuminating gas were filled by water displacement through tubulations at the top and bottom of the jars. All other concentrations were made by liberating ethylene or illuminating gas from vessels which had been inclosed in the inverted bell-jars filled with air and containing the cuttings. The jars were then left closed for 48 hours for the exposure of the cuttings to the gas mixtures, after which they were left open for a like period of time. They then remained sealed for the remainder of the experiment except for the brief intervals of time in which readings were being made. The containers for most of these experiments were inverted bell-jars, as described above; but a like series of experiments made in hermetically sealed four-liter bottles gave essentially the same results.

Although the tests of the ethylene series gave responses with all concentrations except that of pure ethylene, the reaction in the lowest concentration was always weak. The illuminating gas series failed to give intumescences with both the lowest and the highest concentrations. No definite differences in the intensity of the responses for the intermediate concentrations of the two gases were observable. It might be concluded from these experiments that the lowest concentration of the illuminating gas contained an amount of ethylene that was not sufficient to give a response, and that the same concentration of pure ethylene was sufficient to induce only a weak response. This may be correct for the tests with the lowest concentration of the illuminating gas; but, as has been shown above, ethylene

TABLE 10

Effect of various parallel concentrations of ethylene and illuminating gas[1]

TEST NO	DATE	CONCENTRATION OF GAS MIXTURE		NO. OF PIECES	LOCATION OF INTUMESCENCES					
		Ethylene	Illuminating gas		Internodes		Distal ends		Buds	
					Degree	No.	Degree	No.	Degree	No.
1	June 28	*per cent*	*per cent*							
		.05		6	weak	2	none		weak	1
		.5		6	weak	4	medium	4	weak	3
		5.		6	medium	5	weak	2	medium	1
		25.		6	weak	3	medium	5	medium	4
		50.		6	medium	3	strong	3	medium	1
		100.		6	none		none		none	
			.05	6	none		none		none	
			.5	6	weak	1	weak	1	weak	1
			5.	6	weak	3	weak	2	none	
			25.	6	weak	3	weak	4	none	
			50.	6	weak	2	medium	4	none	
			100.	6	none		none		none	

TABLE 10—*Continued*

TEST NO.	DATE	CONCENTRATION OF GAS MIXTURE		NO OF PIECES	LOCATION OF INTUMESCENCES					
		Ethylene	Illuminating gas		Internodes		Distal ends		Buds	
					Degree	No.	Degree	No.	Degree	No.
2	July 8	.05		5	weak	1	weak	1	none	
		.5		5	medium	4	medium	1	strong	5
		5.		5	strong	4	strong	2	maximum	10
		25.		5	medium	5	medium	3	medium	5
		50.		5	strong	4	weak	2	weak	6
		100.		5	none		none		none	
			.05	5	none		none		none	
			.5	5	medium	5	strong	3	weak	5
			5.	5	strong	4	medium	3	strong	4
			25.	5	medium	5	strong	3	medium	8
			50.	5	medium	5	medium	4	medium	5
			100.	5	none		none		none	
3	June 20	.05		6	weak	2	none		weak	1
		.5		6	weak	4	medium	4	none	
		5.		6	medium	5	weak	2	none	
		25.		6	weak	3	strong	5	medium	4
		50.		6	medium	3	strong	3	strong	1
		100.		6	none		none		none	
			.05	6	none		none		none	
			.5	6	weak	1	weak	1	none	
			5.	6	weak	3	weak	2	none	
			25.	6	weak	3	weak	4	weak	1
			50.	6	weak	2	strong	4	none	
			100.	6	none		none		none	
4	July 13	.05		5	weak	1	none		none	
		.5		5	medium	3	strong	5	strong	4
		5.		5	strong	4	medium	2	strong	11
		25.		5	medium	5	strong	4	weak	4
		50.		5	strong	2	strong	4	weak	3
		100.		5	none		none		none	
			.05	5	none		none		none	
			.5	5	none		strong	5	medium	3
			5.	5	strong	5	medium	4	medium	6
			25.	5	strong	3	strong	3	strong	1
			50.	5	medium	2	strong	3	none	
			100.	5	none		none		none	

[1] Exposure time, 48 hours.

has often given strong responses in concentrations much lower than 1 part to 2,000 (0.05 per cent).

The highest concentration of ethylene (100 per cent) did not apparently kill the cuttings nor did it produce observable injury. The highest concentration of illuminating gas (100 per cent), on the other hand, always caused obvious injury and not infrequently killed the cuttings. The higher toxicity of illuminating gas as compared with pure ethylene was unexpected, since other investigators have frequently regarded ethylene as the most toxic constituent for plants of the illuminating gas which they have used.

Effect of mixtures of ethylene with oxygen, nitrogen, and carbon dioxide. A series of experiments with mixtures of oxygen, nitrogen, carbon dioxide, and ethylene, in which the constituents were varied in their relative proportions by increments of 25 per cent, have shown that intumescences may fail to form in the absence of oxygen or in the presence of 25 per cent or more of carbon dioxide. This series of mixtures was made by water displacement, according to the combinations and percentages shown in table 11. When ethylene was not one of the primary constituent gases of the experimental atmosphere, it was added so as to be present as 1 part to 20 parts of the other gases. As shown by the nitrogen-oxygen and oxygen-ethylene series, a percentage of 25 per cent or more of oxygen seemed to have little influence in increasing the intensity of the response. That oxygen is necessary for the occurrence of the response is well shown, however, since no proliferation or swelling of any kind occurred in its absence. The inhibiting influence of 25 per cent or more of carbon dioxide was very pronounced. Such a concentration of carbon dioxide prevented completely the formation of any intumescences even in cases where the oxygen content was four times that of ordinary air.

Relation of exposure time to response. A series of experiments was made to determine the effect of varying the exposure time on the type and character of the intumescences formed. In this series the gas mixture consisted of 1.5 per cent ethylene amd 98.5 per cent air. The exposure time was varied so as to form a series ranging from 7½ minutes to the entire period of the experiment (about two weeks). As shown in table 12, intumescences formed in every case, and there was no apparent

TABLE II

Effect of various gas mixtures on formation of intumescences and abscission of leaves[1]

CONCENTRATION IN GAS MIXTURE				LOCATION OF INTUMESCENCES				ABSCISSION OF LEAVES	
Nitrogen	Oxygen	Carbon dioxide	Ethylene	Internodes		Buds			
				Degree	No.	Degree	No.	Degree	No
per cent	*per cent*	*per cent*	*per cent*						
100	0			none		none		none	
75	25		[2]	strong	3	weak	1	complete	4
50	50			weak	3	strong	4	complete	5
0	75			weak	3	strong	10	complete	5
	100	0		medium	3	medium	3	complete	5
	75	25		none		none		none	
	50	50		none		none		none	
	25	75		none		none		none	
	0	100		none		none		none	
25			75	none		none		none	
50			50	none		none		none	
75			25	none		none		none	
	75		25	medium	3	strong	5	complete	5
	50		50	weak	3	strong	5	complete	5
	25		75	strong	2	maximum	4	complete	3
	0		100	none		none		none	

[1] Test begun July 22; exposure time, throughout the experiment; number of cuttings, five in each set.

[2] When ethylene was not one of the primary constituent gases of the mixture it was added as one part to twenty to the completed mixture.

correlation between length of the exposure time and the intensity of the reaction. In view of the extremely low concentration of ethylene which is sufficient to give a response after an exposure time of one to three days, it is not surprising to find that a concentration of 1.5 per cent gives a response after an exposure time of only 7½ minutes.

GENERAL DISCUSSION

The results reported show that intumescences may develop in the stems of apple in response to stimulation by ethylene gas under a wide range of conditions. My results are somewhat similar to those described by Von Schrenk for the intumescences formed on the leaves of cauliflower in response to stimulation

TABLE 12

Relation of exposure time to formation of intumescences[1]

TEST NO.	DATE	EXPOSURE TIME	NO. OF PIECES	INTUMESCENCES IN DISTAL ENDS OF CUTTINGS	
				Degree	No.
1	Oct. 15	7½ min.	5	weak	4
		15 min.	5	weak	3
		30 min.	5	weak	4
		1 hr.	5	weak	4
		2 hr.	5	weak	4
		4 hr.	5	weak	3
		8 hr.	5	weak	3
		16 hr.	5	weak	4
		24 hr.	5	weak	3
		continuous	5	medium	3
2	Nov. 8	7½ min.	5	medium	4
		15 min.	5	weak	5
		30 min.	5	weak	4
		1 hr.	5	weak	5
		2 hr.	5	weak	3
		4 hr.	5	weak	3
		8 hr.	5	weak	1
		16 hr.	5	medium	2
		24 hr.	5	medium	4
		continuous	5	weak	5

[1] Composition of ethylene-air mixture: 1.5 per cent ethylene and 98.5 per cent air.

by dilute solutions of copper. It is not at all clear why chemical stimulation by ethylene, copper solutions, etc., should induce the production of intumescences so similar to those reported by Sorauer, Küster, and others to arise in response to abnormal conditions of the physical environment, such as weak light, excessive humidity, and high temperature. Von Schrenk found, so far as he studied, that the formation of intumescences on cauliflower was not influenced by variations in these environmental conditions. I find that the production of intumescences on the stems of the apple in response to ethylene gas is little influenced by conditions of light intensity or of humidity. There is evidently no summation in these cases of chemical with light or moisture stimuli. Differences in temperature, on the other hand, have a marked effect on the number and size of the intumescences formed by ethylene. The optimum appears from my results to be near 15° C., while the maximum seems to lie slightly above 30° C. According to Sorauer's view the opposite would be expected in case the ethylene and temperature stimuli do not antagonize each other.

The formation of intumescences in the bark and in the buds of woody stems seems to be one of the most pronounced responses to chemical stimulation so far reported for plants, viewed from the standpoint of the amount of the stimulus required to initiate the reaction. My results have shown even greater sensitiveness to ethylene than has been reported by other investigators.

Crocker and Knight (1908) found that flowers of the carnation close after exposure for twelve hours to 1 part of ethylene to 3,000,000 parts of air. The etiolated epicotyl of the sweet pea (Crocker, Knight, and Rose, 1913) was inhibited in its rate of growth when only 1 part of ethylene to 10,000,000 parts of air was present. E. M. Harvey (1913) reported definite droopings of the leaves and petioles of the castor bean plant in a similar concentration of ethylene, but mentioned that proliferation at the abscission layer failed to occur in concentrations lower than 1 part to 500,000 parts of air. It appears, therefore, that intumescence formation in the stems of Transparent apple is an even more delicate test for traces of this gas.

As described, I have obtained positive responses on cuttings of Transparent apple with 1 part of ethylene to 100,000,000 parts of air. My results indicate that the response in the distal ends of such cuttings may be more consistant and definite than those occurring in the buds and in the internodes. This stronger response at the distal end of a cutting may result from a more rapid penetration of the gas in this region. It is not clear that polarity has any influence on the response. Further experiments on these points are needed.

The fact that the entire range of concentrations of ethylene from extremely high to extremely low induce the formation of very similar outgrowths is in interesting contrast to what is regarded, in general, as the effect of so-called toxic agents on living organisms. Such substances retard growth or kill when used in large amounts, and many of them stimulate when used in small amounts. We have abundant evidence from the studies of Neljubow (1901), Crocker and Knight (1908), and others that ethylene may be extremely toxic to some plants or plant parts, and may prove lethal when present in the merest traces.

That ethylene may hasten the disappearance of chlorophyll in some plants and plant parts has been well shown by the work of Denny (1924), Rose (1925b), and others. In view of this, it is all the more noteworthy that the chlorenchyma of stems of apple shows no decrease in the chlorophyll content when treated with this gas, in either high or low concentrations. Studies by E. M. Harvey (1913) and Denny (1923) indicate that ethylene increases the rate of plant metabolism. The disappearance of chlorophyll in materials treated with ethylene may not be a direct effect of the ethylene itself, but rather an indirect effect due to the resultant increased rates of the metabolic activities of the treated materials. All materials, such as the fruits of lemons and tomatoes and leaves of celery, which have shown an acceleration in the disappearance of chlorophyll when treated with ethylene are tissues from which the chlorophyll has already begun to disappear, or from which it soon would normally disappear. Since the chlorenchyma of stems would normally retain its green color, it is perhaps only natural to find that for it ethylene treatment does not result in bleaching.

SUMMARY

Extensive experiments made on cuttings of Transparent apple have shown that ethylene stimulation may induce the formation of intumescences under a wide range of environmental and biological conditions. Materials collected from different parts of the same individual or from different individuals of the same variety showed no apparent variation in the nature or extent of the reactions. Tests made during every month of the year indicate no pronounced seasonal or periodic variation in the sensitiveness of the tissues to ethylene stimulation. Humidities ranging from 67 per cent to 92 per cent have no apparent effect on the ethylene response. No correlation was apparent between the number or extent of the intumescences and the percentage of humidity.

Temperature exerts a marked influence on the number and size of the intumescences. The optimum temperature for their formation is near 15° C., while 30° C. is about the maximum at which they will form. A much larger relative number of the cuttings responded at the optimum than at higher temperatures.

The intumescences form equally well in continuous light, continuous darkness, or in alternate light and darkness.

Ethylene and illuminating gas gave about the same responses when run in parallel series of concentrations from .05 to 50 per cent.

Intumescences do not form in the absence of oxygen. They do not develop in the presence of 25 per cent or more of carbon dioxide.

Mixtures varying all the way from 75 per cent of ethylene and 25 per cent of oxygen to 1 part of ethylene to 1,000,000 or 100,000,000 parts of air will induce the formation of intumescences at least in the ends of cuttings of Transparent apple. No definite differences in the extent or number of the responses were observed for concentrations ranging from 75 per cent ethylene and 25 per cent of oxygen to 1 part of ethylene to 10,000 parts of air. Intumescences formed in concentrations of ethylene of 1 part to 1,000,000 or 100,000,000 parts of air were much less extensive and were slower in appearing than those in the higher concentrations, but they were none-the-less distinct and characteristic.

Exposures to a mixture of 1.5 per cent ethylene and 98.5 per cent air for periods ranging from 7½ minutes to continuous exposure through the experimental period all gave responses. No variation was observed in the number or extent of the intumescences formed with this range of exposure times.

Ethylene appeared to have no bleaching effect on the chlorenchyma of the stems of Transparent apple.

I wish to express my appreciation to Professor R. A. Harper for stimulating criticism and invaluable assistance during the progress of these studies and in the preparation of this paper. I also greatly appreciate the Edna L. Smith fellowship in botany which made possible the completion of these studies.

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Literature Cited

Atkinson, G. F. 1893a. Oedema of the tomato. Bull. Cornell Agr. Exp. Sta. 53: 1–108. pl. 1–8.

————. 1893b. Oedema of apple trees. Bull. Cornell Agr. Exp. Sta. 61: 299–302. fig. 1, 3.

Bayliss, J. S. 1907. On the galvantropism of roots. Ann. Bot. **21:** 387–405.

Crocker, W., and L. I. Knight. 1908. Effect of illuminating gas and ethylene upon flowering carnations. Bot. Gaz. **46:** 259–276.

————, **L. I. Knight, and R. C. Rose.** 1913. A delicate seedling test. Science **37:** 380–381.

Dale, E. 1901. Investigations on abnormal outgrowths or intumescences on *Hibiscus vitifolius.* Phil. Trans. Roy. Soc. London B **194:** 163.

————. 1899. Intumescences on *Hibiscus vitifolius.* Ann. Bot. **13:** 622–624.

Davis, H. V. 1910. Notes on certain intumescences in roots. New Phytologist **9:** 325–326.

Denny, F. E. 1924. Effect of ethylene upon respiration of lemons. Bot. Gaz. **77:** 322–329.

Doubt, S. L. 1917. The response of plants to illuminating gas. Bot. Gaz. **63:** 209–225. fig. 1–6.

Douglas, G. E. 1907. The formation of intumescences on potato plants. Bot. Gaz. **43:** 233–250.

Fujii, K. 1925. Ueber die Entlassung der Spermatozoiden von *Isoëtes.* Flora N. Ser. **18–19:** 115–126.

Haberlandt, G. 1899. Ueber experimentalle Hervorrufung eines neuen Organs bei *Conocephalus ovatus* Trec. Festchr. f. Schwendener, p. 104–119. fig. 1, 2.

Hahn, G. G., C. Hartley, and A. Rhoads. 1920. Hypertrophied lenticels on the roots of conifers and their relation to moisture and aeration. Jour. Agr. Res. **20:** 253–266.

Harvey, E. M. 1913. The castor bean plant and laboratory air. Bot. Gaz. **56:** 439–442.

————. 1915. Some effects of ethylene upon the metabolism of plants. Bot. Gaz. **60:** 193–214. fig. 1, 2.

————, **and R. C. Rose.** 1915. The effect of illuminating gas on root systems. Bot. Gaz. **60:** 27–44. fig. 1–8.

Harvey, R. B. 1925. Blanching of celery. Univ. Minnesota Agr. Exp. Sta. Bull. 222: 1–20. fig. 1–10.

Küster, E. 1903a. Pathologische Pflanzenanatomie.

————. 1903b. Ueber experimentelle erzeute Intumeszenzen. Ber. deutsch. Bot. Ges. **21:** 452–458.

Luckhardt, A. B., and J. B. Carter. 1923. Ethylene as a gas anaesthetic, preliminary communication. Jour. Am. Med. Assoc. **80:** 1440–1442.

Molz. 1906. Dropsy of the grape. Ber. der Kgl. Lehranstalt zu Geisenheim a. Rhein. (Cited by Sorauer.)

Norack, F. 1901. Eine Treibhauskrankheit der Weinreibe. Gartenflora **50**: 619–622

Nägeli. 1893. Oligodynamische Erscheinungen in lebenden Zellen. Denkschr. der Schweiz. Naturf. Ges. **33.**

Neljubow, D. 1901. Ueber die horizontale Nutation der Stengel von *Pisum sativum* und einiger anderen Pflanzen. Beih. Bot. Centralbl. **10**: 128–138.

Prillieux, Ed. 1892. Intumescences sur les feuilles d'oeillets malades. Bull. d. l. Soc. d. France **39**: 370.

Rose, J. T. 1925a. Shortening the rest period of potatoes with ethylene gas. Potato News Bull. **2**: 363–365.

————. 1925b. Physiological effects of ethylene on green mature tomato fruits. Absts. Plant Physiol. Sect. Bot. Soc. Amer., Kansas City, Missouri, 1925.

Rosen, H. R. 1916. The development of the *Phylloxera vasterix* leaf gall. Am. Jour. Bot. **3**: 337–360.

Rumbold, C. 1916. Pathological anatomy of the injected trunks of chestnut trees. Proc. Am. Phil. Soc. **55**: 485–493. pl. 15–18.

Schilling, E. 1915. Ueber hypertropische und hyperplastische Gewebeswucherungen an Sprossachsen, Versacht durch Paraffine. Jahrb. Wiss. Bot. **55**: 177–258. fig. 1–43.

Smith, E. F. 1917. Mechanism of tumor growth in crowngall. Jour. Agr. Res. **8**: 165–189. pl. 4–65.

Sorauer, P. 1886. Handbuch der Pflanzenkrankheiten. Auflage 1.

————. 1892. Nachweis der Verweichlichung unserer Obstbäume durch die Kulture. Zeit. f. Pflanzenkrankh. p. 66.

————. 1899. Ueber Intumeszenzen. Ber. deutsch. Bot. Ges. **17**: 456–460.

Steiner, R. 1905. Ueber Intumeszenzen bei *Rueillia formosa* und *Aphelandra Porteana*. Ber. deutsch. Bot. Ges. **23**: 105–113.

Stone, G. E. 1913. The effect of illuminating gas on vegetation. Ann. Rept. Massachusetts Exp. Sta. **25**: 45–60. fig. 1–3.

Taylor, W. R. 1919. On the production of new cell formations in plants. Contrib. Univ. Pennsylvania Bot. Lab. **4**: 271–299. pl. 71–78.

Trotter, A. 1904. Intumescenzes fogliari di *Ipomaea Batatas*. Annali di Botanica **1**: 365.

Viala, P., and P. Pacottet. 1904. Sur les verrues des feuilles de la vigne. Compt. Rend. de s. d. l'Acad. d. Sci. **138**: 163.

Von Schrenk, H. 1905. Intumescences formed as a result of chemical stimulation. Rept. Missouri Bot. Gard. **16**: 125–148. pl. 25–31.

Wallace, R. H. 1926. The production of intumescences upon apple twigs by ethylene gas. Bull. Torrey Bot. Club **53**: 385–401. pl. 14–15.

Wisniewski, P. 1910. Ueber Induktion von Lenticellenwucherungen bei *Ficus*. Bull. d. l'Acad. d. Sci. de Cracovoie. Ser. B Sci. Naturelles, no. 5, B, May, 1910. p. 359–367. 2 pl.

Wolf, F. A. 1918. Intumescences, with a note on mechanical injury as a cause for their formation. Jour. Agr. Res. **13**: 253–259.

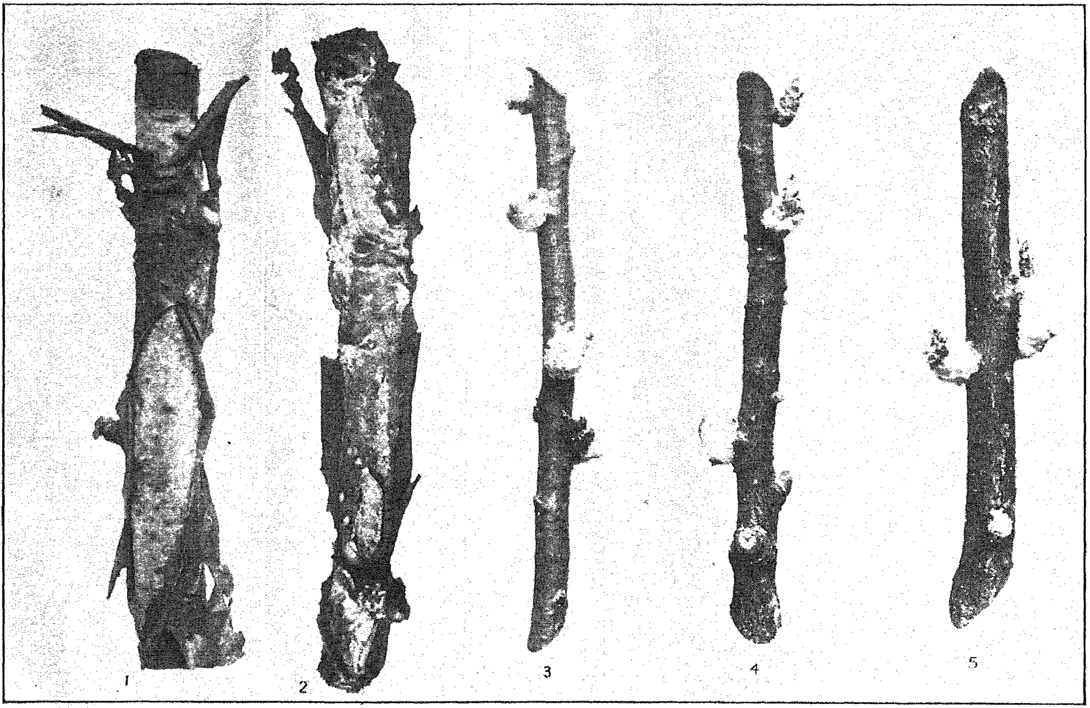
Explanation of Plate

PLATE 34

Fig. 1. Wide-spread but superficial intumescences on an internode of Transparent apple (× 1.5). The dead corky layers have been split and rolled back. The chlorenchyma and the deeper tissues are apparently normal.

Fig. 2. Wide-spread and deep-seated intumescences on an internode of Transparent apple (× 1.5). The chlorenchyma is somewhat exposed, but most of the response is localized in the deeper lying tissues.

Figs. 3, 4, and 5. Three cuttings of *Populus deltoides* (× 0.7) showing intumescences at the base of buds (one month after exposure to ethylene). Note that the tissue masses of the intumescences are more or less coherent and not loose and granular as they are in portions of the intumescences shown in figure 2.



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Aamodt, O. S. Breeding wheat for resistance to physiologic forms of stem rust. Jour. Am. Soc. Agron. **19**: 206–218. Mr 1927.

Anderson, H. W. The effect of sodium silicofluoride sprays on the peach and on the control of bacterial spot. Science II, **65**: 16–18. 7 Ja 1927.

Angst, L. The gametophyte of *Soranthera ulvoidea*. Publ. Puget Sound Biol. Sta. **5**: 159–162. *pl. 9.* D 1926.

Artschwager, E. Development of flowers and seed in the sugar beet. Jour. Agr. Res. **34**: 1–25. *f. 1–15* + *pl. 1.* 1 Ja 1927.

Atanasoff, D. Net necrosis of potato. Phytopathology **16**: 929–940. *f. 1–5.* 15 D 1926.

Bailey, D. L. Physiologic specialization in *Puccinia graminis avenae* Erikss. and Henn. Minnesota Agr. Exp. Sta. Tech. Bull. 35: 1–33. *pl. 1–7.* D 1925.

Bakke, A. L., Richey, H. W., and Reeves, K. Germination and storage of apple seeds. Iowa Agr. Exp. Sta. Res. Bull. 97: 243–255. *pl. 1, 2.* O 1926.

Bartram, E. B. Notes on *Mielichhoferia*. Bull. Torrey Club **54**: 31–34. *f. 1–20.* "Ja" 22 F 1927.

Bates, C. G. Better seeds, better trees. Jour. For. **25**: 130–144. *illust.* F 1927.

Belling, J. Multiple chromosomes and reduction division in flowering plants. Nature **119**: 122. 22 Ja 1927.

Berkeley, G. H. Studies in tomato streak. Sci. Agr **7:** 210–223. *f. 1–4.* F 1927.

B[erry], E. W. Frank Hall Knowlton. Science II, **65:** 7–8. 7 Ja 1927.
Born 2 S 1860. Died 22 N 1926.

Berry, E. W. Frank Hall Knowlton, 1860–1926. Am. Jour. Sci. V, **13:** 281–282. Mr 1927.
Born 2 S 1860. Died 22 N 1926.

Berry, E. W. The term Oligocene and certain climatic considerations. Am. Jour. Sci. V, **13:** 252–256. Mr 1927.

Black, J. M. *Olearia v. Shawia.* Jour. Bot. **65:** 17–18. Ja 1927.

Blake, S. F. New Asteraceae from Costa Rica. Jour. Washington Acad. Sci. **17:** 59–65. *illust.* 3 F 1927.
Two species in *Gnaphalium* and three in *Hieracium.*

Blakeslee, A. F. The chromosomal constitution of Nubbin, a compound (2n + 1) type in *Datura.* Proc. Natl. Acad. Sci. **13:** 79–85. *f. 1–4.* 15 F 1927.

Boyce, J. S. Observations on forest pathology in Great Britain and Denmark. Phytopathology **17:** 1–18. 15 Ja 1927.

Boyer, C. S. List of Quaternary and Tertiary Diatomaceae from deposits of southern Canada. Victoria Mem. Mus. Bull. Biol. Ser. 45: 1-26. 9 N 1926.

Breazeale, J. F. Alkali tolerance of plants considered as a phenomenon of adaptation. Arizona Agr. Exp. Sta. Tech. Bull. 11: 239–256. *f. 1–4.* 1 N 1926.

Britton, N. L. Studies of the Mimosas. Jour. N. Y. Bot. Gard. **28:** 67–68. Mr 1927.

Broadfoot, W. C. Studies on the parasitism of *Fusarium lini* Bolley. Phytopathology **16:** 951–978. *f. 1, 2.* 15 D 1926.

Brooks, M. M. Studies on the permeability of living cells, VII. The effects of light of different wave lengths on the penetration of 2,-6,-dibromo phenol indophenol into *Valonia.* Protoplasma **1:** 305–312. *f. 1, 2.* D 1926.

Brotherus, V. F. Contributions to the bryological flora of the Philippines, VI. Philipp. Jour. Sci. **31**: 277–300. N 1926.
Several species described as new.

Brown, H. B. The use of first generation crosses and other methods for improving southern varieties of corn. Mississippi Agr. Exp. Sta. Bull. 236: 1–31. *f. 1–3.* Jl 1926.

Brown, N. A. Sweet pea fasciation, a form of crowngall. Phytopathology **17**: 29–30. *pl. 1, 2.* 15 Ja 1927.

Burkholder, W. H. A new bacterial disease of the bean. Phytopathology **16**: 915–927. *f. 1, 2 + pl.* 55. 15 D 1926.
Phytomonas medicaginis var. *phaseolicola.*

Christensen, J. J., and Stakman, E. C. Physiologic specialization and mutation in *Ustilago zeae.* Phytopathology **16**: 979–999. *f. 1–11.* 15 D 1926.

Chun, W. Y. New species and new combinations of Chinese plants. Jour. Arnold Arbor. **8**: 19-22. "Ja" 28 F 1927.
In *Ostrya, Cercis, Castanopsis, Lithocarpus, Vanieria, Phoebe, Notaphoebe, Benzoin, Actinodaphne,* and *Neolitsea.*

Clayton, E. E. Control of seedbed diseases of cruciferous crops on Long Island by the mercuric chloride treatment for cabbage maggot. N. Y. (Geneva) Agr. Exp. Sta. Bull. 537: 1–29. D 1926.

Clute, W. N. James H. Ferriss. Am. Fern Jour. **16**: 103–106. "D 1926" 2 F 1927.
Born 18 N 1849. Died 17 Mr 1926.

Coleman, D. A., Fellows, H. C., and Dixon, H. B. Testing wheat for protein, with a recommended method for making the test. U. S. Dept. Agr. Bull. 1460: 1–32. *f. 1–3.* D 1926.

Collings, G. H. The influence of boron on the growth of the soybean plant. Soil Sci. **23**: 83–104. *pl. 1.* F 1927.

Conklin, G. H. Collecting hepatics along Lake Superior in northern Minnesota. Bryologist **30**: 6-8. "Ja" Mr 1927.

Cook, M. T. Relationship of cane varieties to diseases. Jour. Dept. Agr. Porto Rico **9**: 277–281. O 1925.

Cook, O. F., and Hubbard, J. W. Primitive cottons in Mexico. Characters of native cottons including a wild species. Jour. Hered. **17**: 463–472. *f. 10–15*. "D 1926" 12 F 1927.

Coulter, J. M. The contribution of science to the welfare of the nation. Sci. Mo. **24**: 193–205. Mr 1927.

Dearness, J. *Amanita* poisoning. Mycologia **19**: 93–94. 1 Mr 1927.

Deatrick, E. P. Porous clay auto-irrigator cones for watering potted soil and plants. Jour. Am. Soc. Agron. **19**: 252. *f. 1, 2*. Mr 1927.

Dickey, L. B. The avocado and vitamines. Science II, **65**: 15. 7 Ja 1927.

Drayton, F. L., comp. A summary of the prevalence of plant diseases in the Dominion of Canada 1920–1924. Canada Dept. Agr. Bull. n. s. 71: 1–88. 1926.

Dungan, G. H. The influence of plant injury and the root rot diseases upon the physical and chemical composition of corn grain. Illinois Agr. Exp. Sta. Bull. 284: 253–281. *f. 1–9*. D 1926.

Durrell, L. W., and Lungren, E. A. Barberry eradication and sources of black stem rust in Colorado. Colorado Agr. Exp. Sta. Bull. 315: 1–18. *f. 1–10*. Ja 1927.

Emerson, R. The effect of certain respiratory inhibitors on the respiration of *Chlorella*. Jour. Gen. Physiol. **10**: 469–477. *f. 1–6*. 20 Mr 1927.

Essary, S. H. Two important tomato diseases and their control. Tennessee Agr. Exp. Sta. Circ. 8: 1–4. *illust*. Ja 1927.
Wilt and leaf-spot.

Evans, A. W., and Meyrowitz, R. Catalogue of the lichens of Connecticut. Connecticut Geol. & Nat. Hist. Surv. Bull. 37: 1–49. 1926.

Faris, J. A. Zonate food rot of sugar cane. Phytopathology **17**: 83–94. *f. 1–10*. 15 F 1927.

Faris, J. A., and Allison, R. V. Sugar cane root disease in Cuba: a progress report upon the root disease situation in 1925. Phytopathology **17:** 61–82. *f. 1–11.* 15 F 1927.

Farwell, O. A. Botanical gleanings in Michigan IV. Am. Midl. Nat. **10:** 199–219. Ja 1927.

Fassett, N. C. *Hieracium canadense* var. *hirtirameum* in northern Michigan. Rhodora **28:** 246. "D 1926" 28 Ja 1927.
Isle Royale.

Fassett, N. C. Notes on the flora of Boothbay, Maine—II. Rhodora **29:** 14–15. 28 Ja 1927.

Fernald, M. L. *Muhlenbergia uniflora.* Rhodora **29:** 10–14. 28 Ja 1927.
1 variety and 1 combination described as new.

Fernald, M. L. Two summers of botanizing in Newfoundland. Rhodora **28:** 49–63; 74–87; 89–111; 115–129; 145–155; 161–178; 181–204; 210–225; 234–241. *pl. 153–155.* 11 My; 11 Je; 22 Jl; 8 S; 20 S; 6 N; 20 D 1926; 28 Ja 1927.

Fisk, E. L. The chromosomes of *Zea mays.* Am. Jour. Bot. **14:** 53–75. *pl. 10.* "F" 8 Mr 1927.

Fleming, C. E., Miller, M. R., and Vawter, L. R. The common chokecherry (*Prunus demissa*) as a plant poisonous to sheep and cattle. Nevada Agr. Exp. Sta. Bull. 109: 1–30. *illust.* Mr 1926.

Flor, H. H. Fungicidal activity of furfural. Iowa State Coll. Jour. Sci. **1:** 199–223. Ja 1927.

Foote, Mrs. E. M. Ferns of Cornwall, Connecticut. Am. Fern Jour. **16:** 124–127. "D 1926" 2 F 1927.

Gager, C. S., and Blakeslee, A. F. Chromosome and gene mutations in *Datura* following exposure to radium rays. Proc. Natl. Acad. Sci. **13:** 75–79. 15 F 1927.

Gaines, E. F. The relation of triploid factors and chromosome groups in wheat and oats. Jour. Am. Soc. Agron. **19:** 202–205. Mr 1927.

Garber, R. J., and Quisenberry, K. S. The inheritance of length of style in buckwheat. Jour. Agr. Res. **34**: 181–183. 15 Ja 1927.

Garber, R. J., and Quisenberry, K. S. Natural crossing in oats at Morgantown, West Virginia. Jour. Am. Soc. Agron. **19**: 191–197. F 1927.

Garber, R. J., and Quisenberry, K. S. Self-fertilization in buckwheat. Jour. Agr. Res. **34**: 185–190. *f. 1.* 15 Ja 1927.

Gardner, N. L. New Rhodophyceae from the Pacific coast of North America. II. Univ. California Publ. Bot. **13**: 235–272. *pl. 24–35.* 28 F 1927.

Gill, T. The lifeblood of trees. Nat. Mag. **9**: 177–180. *illust.* Mr 1927.

Gleason, H. A. Four new Melastomataceae from Peru. Bull. Torrey Club **54**: 25–29. "Ja" 22 F 1927.

In *Axinaea*, *Tibouchina* and *Brachyotum*.

Gloyer, W. O. The dwarfing, shriveling, and dropping of cherries and prunes. New York (Geneva) Agr. Exp. Sta. Bull. 540: 1–18. *pl. 1–4.* D 1926.

Gravatt, A. Rathbun. A witches' broom of introduced Japanese cherry trees. Phytopathology **17**: 19–24. *f. 1.* 15 Ja 1927.

Grier, N. M. Mr. Taylor vs. "Grier's Notes on the Flora of Long Island." Rhodora **28**: 242–245. "D 1926" 28 Ja 1927.

Grier, N, M. A note on the interrupted fern. Torreya **27**: 8–9. F 1927.

Osmunda claytoniana.

Grout, A. J. Studies in *Ditrichum*. Bryologist **30**: 4–5. Ja 1927.

D. tortuloides described as new.

Haenseler, C. M. Plant diseases of New Jersey (twelfth instalment). Pea diseases. New Jersey Agr. 9^2: 6–7. F 1927.

Hahn, G. G. *Phomopsis juniperovora* and closely related strains on conifers. Phytopathology **16**: 899–914. *f. 1* + *pl. 52–54.* 15 D 1926.

Harland, S. C., Haigh, J. C., and Lochrie, J. L. On a progressive variation with age of a simple Mendelian ratio in the cowpea. Genetica **8**: 507–512. 1926.

Harper, R. M. A six-hour cross-section of the vegetation of southern Ontario. Torreya **27**: 1–8. F 1927.

Harris, J. A. The cat tail, *Typha angustifolia*, in Utah. Torreya **27**: 9–11. F 1927.

Harris, T. M. The rhaetic flora of Scoresby Sound, East Greenland. Meddel. Grønland **68**: 45–147. *f. 1–34* + *pl. 1–13.* 1926.

Hartley, C. Notes on *Hibiscus* diseases in West Java. Phytopathology **17**: 25–27. 15 Ja 1927.

Hauman, L. Étude phytogéographique de la Patagonie. Bull. Soc. Roy. Bot. Belg. **58**: 105–179. *f. 1–7* + *pl. 1–13.* 1926.

Henderson, N. F. Ohio mosses, Bryales. Ohio Jour. Sci. **27**: 1–18. "Ja" 15 F 1927.

Holm, T. The flower of *Chimaphila*. Rhodora **29**: 1–6. *pl. 156.* 28 Ja 1927.

Holm, T. Sciaphilous plant-types. Beihefte Bot. Centralbl. Abt. I, **44**: 1–89. *f. 1–3.* Ja 1927.

Hope, A. The dissemination of weed seeds by irrigation water in Alberta. Sci. Agr. **7**: 268–276. Mr 1927.

Humbert, E. P., and Mogford, J. S. Variation in certain lint characters in a cotton plant and its progeny. Texas Agr. Exp. Sta. Bull. 349: 1–23. *f. 1–4.* F 1927.

Hunt, W. R. The Uredinales or rusts of Connecticut and the other New England states. Connecticut Geol. & Nat. Hist. Surv. Bull. 36: 1–198. 1926.

Hurd-Karrer, A. M., and Hasselbring, H. Effect of smut (Ustilago zeae) on the sugar content of cornstalks. Jour. Agr. Res. **34**: 191–195. 15 Ja 1927.

Jackson, A. B. The *Fusarium* wilt of China asters. Sci. Agr. 7: 233–247. *pl. 1–3.* Mr 1927.

Jackson, H. S. The rusts of South America based on the Holway collections—II. Mycologia **19:** 51–65. 1 Mr 1927.
Many species described as new.

Jagger, I. C. Powdery mildew of muskmelons in the Imperial Valley of California in 1925. Phytopathology **16:** 1009–1010. 15 D 1926.

Jennings, O. E. Meanings of some plant names. Bull. Gard. Club Am. 13: 16–19. Ja 1927.

Johnston, C. O. Effects of soil moisture and temperature and of dehulling on the infection of oats by loose and covered smuts. Phytopathology **17:** 31–36. 15 Ja 1927.

Johnston, I. M. Studies in the Boraginaceae—VI. A revision of the South American Boraginoideae. Contr. Gray Herb. 78: 1–118. 15 Mr 1927.
Many species described as new.

Kern, F. D. A trip to Santo Domingo. Sci. Mo. **23:** 529–538. D 1926.

Kern, F. D., and Whetzel, H. H. Hemibasidiomycetes. (in Seaver, F. J., & Chardon, C. E. Botany of Porto Rico and the Virgin Islands. Mycology. Sci. Survey Porto Rico, 8: 107–144. 29 D 1926.)

Keyes, F. J. *Trillium grandiflorum* in Maine. Rhodora **29:** 15. 28 Ja 1927.
At Chesterville.

Kidder, A. V. Eskimos and plants. Proc. Natl. Acad. Sci. **13:** 74–75. 15 F 1927.

Kirk, L. E. Breeding improved varieties of forage crops. Jour. Am. Soc. Agron. **19:** 225–239. Mr 1927.

Kirkwood, J. E. Botanical exploration in the Rocky Mountains. Sci. Mo. **24:** 236–250. Mr 1927.

Kittredge, E. M. A remarkable form of walking fern. Am. Fern. Jour. **16:** 98–100. *pl. 8.* 28 S 1926.

Lantz, C. W. Respiration in corn with special reference to catalase. Am. Jour. Bot. **14**: 85–105. *pl. 1–4.* "F" 8 Mr 1927.

LaRue, C. D. The Hevea rubber tree in the Amazon Valley. U. S. Dept. Agr. Bull. 1422: 1–69. O 1926.

Leighty, C. E. Breeding plants for disease resistance. Jour. Am. Soc. Agron. **19**: 219–225. Mr 1927.

Leonard, E. C. The North American species of *Scutellaria.* U. S. Natl. Herb. Contr. **22**: i–vii, 703–748. 1927.

Letcher, H., and Willaman, J. J. Biochemistry of plant diseases. VIII. Alcoholic fermentation of *Fusarium lini.* Phytopathology **16**: 941–949. *f. 1–3.* 15 D 1926.

Lillibridge, A. E. Some abnormal forms of *Botrychium simplex.* Am. Fern Jour. **16**: 127–128. *pl. 11.* "D 1926" 2 F 1927.

Lindstrom, E. W., and Gerhardt, F. Inheritance of carbohydrates and fat in crosses of Dent and sweet corn. Iowa Agr. Exp. Sta. Res. Bull. 98: 259–277. N 1926.

Linford, M. B. Additional hosts of *Aphanomyces euteiches,* the pea rootrot fungus. Phytopathology **17**: 133–134. 15 F 1927.

Lute, A. M. Alfalfa seed made permeable by heat. Science II, **65**: 166. 11 F 1927.

Lutz, B. Estudos sobre a biologia floral de *Mangifera indica* L. Arch. Mus. Nac. Rio. de Janeiro **26**: 125–158. *pl. 1–4.* 1926.

MacGillivray, J. H. Effect of phosphorus on the composition of the tomato plant. Jour. Agr. Res. **34**: 97–127. *f. 1–6.* 15 Ja 1927.

McHargue, J. S. Significance of the occurrence of manganese, copper, zinc, nickel and cobalt in Kentucky blue grass. Ind. and Eng. Chem. **19**: 273–276. *illust.* F 1927.

Mackenzie, K. K. Further light on our purple-flowered Eupatoriums. Rhodora **29**: 6–9. 28 Ja 1927.

Mackenzie, K. K. *Solidago conferta* Miller. Rhodora **29:** 17–19. "F" 28 Ja 1927.

Mackenzie, K. K. Technical name of sugar maple. Rhodora **28:** 233–234. "D 1926" 28 Ja 1927.

Mackenzie, K. K. Usage. Rhodora **29:** 26–32. "F" 28 Ja 1927.

MacMillan, H. G. A method of growing bacteriologically sterile potato plants. U. S. Dept. Agr. Bull. 1465: 1–21. *f. 1–6 + pl. 1–6.* Ja 1927.

McNair, J. B. Citrus products. I. Publ. Field Mus. Nat. Hist. Bot. Ser. **6:** 1–212. *pl. 1–6.* Au 1926.

Mangels, C. E. A study of dark, hard kernel and protein content of hard red spring wheat. Jour. Agr. Res. **34:** 157–166. *f. 1–6.* 15 Ja 1927.

Mangelsdorf, P. C. Progress and possibilities in forage crop improvement. Jour. Am. Soc. Agron. **19:** 239–242. Mr 1927.

Markgraf, F. Neue Apocynaceen aus Südamerika. II. Notizbl. Bot. Gart. Berlin **9:** 959–963. 15 N 1926.

Mattoon, W. R. Loblolly pine primer. U. S. Dept. Agr. Farmers Bull. 1517: 1–38. *f. 1–27.* D 1926.

Meisel, M. A bibliography of American natural history. The pioneer century, 1769–1865. Vol. II. The institutions which have contributed to the rise and progress of American natural history, which were founded or organized between 1769 and 1844. 1-741. 1927.

Melander, L. W., and Craigie, J. H. Nature resistance ~~of~~ *Berberis* spp. to *Puccinia graminis.* Phytopathology **17:** 95–114. *f. 1–4.* 15 F 1927.

Melchior, H. Plantae Steinbachianae. Botizbl. Bot. Gart. Berlin **9:** 1034–1043. 15 N 1926.
Several species described as new.

Mendiola, N. B. Imperfect hermaphroditism in flowers of *Hibiscus*, removed by surgical operation. Philipp. Jour. Sci. **32:** 65–74. *pl. 1–4.* Ja 1927.

Merrill, E. D. New Chinese ligneous plants. Jour. Arnold Arbor. **8:** 3–19. "Ja" 28 F 1927.

Two genera, *Phoebe* and *Bennettiodendron* as well as many species, described as new.

Milbraed, J. Plantae tessmannianae peruvianae III. Notizbl. Bot. Gart. Berlin **9:** 964–977. 15 N 1926.

2 genera, *Tessmanniacanthus* and *Aphelandrella,* as well as many species, described as new.

Mowry, H. Palms of Florida. Florida Agr. Exp. Sta. Bull. 184: 1–54. *f. 1–57.* O 1926.

Moxley, E. A. Some November notes from Owen Sound, Ontario. Bryologist **30:** 8. "Ja" Mr 1927.

Murneek, A. E. Physiology of reproduction in horticultural plants. I. Reproduction and metabolic efficiency in the tomato. Missouri Agr. Exp. Sta. Res. Bull. 90: 1–19. S 1926.

Murrill, W. A. The edibility of *Leotia.* Mycologia **19:** 92. 1 Mr 1927.

Murrill, W. A. *Spongipellis fissilis.* Mycologia **19:** 90–91. 1 Mr 1927.

Navez, A. E. "Galvanotropism" of roots. Jour. Gen. Physiol. **10:** 551–558. *f. 1.* 20 Mr 1927.

Nelson, C. I., and Dworak, M. Studies on the nature of wilt resistance in flax. North Dakota Agr. Exp. Sta. Bull. 202: 1–30. *f. 1.* S 1926.

Nolla, J. A. B. A new *Alternaria* disease of onions (*Allium cepa* L.) Phytopathology **17:** 115–132. *pl. 3–5.* 15 F 1927.

A. allii.

Overholts, L. O. Eubasidiomycetes. (in Seaver, F. J., & Chardon, C. E. Botany of Porto Rico and the Virgin Islands. Mycology. Sci. Survey Porto Rico **8:** 145–181.) 29 D 1926.

Pack, A. N. Garden nature. Nat. Mag. **9:** 167–170. [*8*] *col. pl.* Mr 1927.

Palmer, E. J. On Nuttall's trail through Arkansas. Jour. Arnold Arbor. **8:** 24–55. "Ja" 28 F 1927.
Quercus Nuttallii described as new.

Platz, G. A., Durrell, L. W., and Howe, M. F. Effect of carbon dioxide upon the germination of chlamydo-spores of *Ustilago zeae* (Beckm.). Ung. Jour. Agr. Res. **34:** 137–147. *f. 1–3.* 15 Ja 1927.

Plitt, C. C. Succession in lichens. Bryologist **30:** 1–4. "Ja" Mr 1927.

Pretz, H. W. On *Eragrostis peregrina* and its relatives. Rhodora **29:** 19–26. "F" 28 Ja 1927.

Randolph, F. R. A cytological study of two types of variegate pericarp in maize. New York (Cornell) Agr. Exp. Sta. Memoir 102: 1–14. *f. 1–4* + *pl. 1, 2.* Au 1926.

Record, S. J. A new species of *Mollia* of British Guiana. Yale Univ. School For. Tropical Woods 9: 8–10. 1 Mr 1927.
M. sphaerocarpa.

Record, S. J. Occurrence of "ripple marks" in woods. Yale Univ. School For. Tropical Woods 9: 13–18. 1 Mr 1927.

Reed, H. S. Growth and differentiation in plants. Quar. Rev. Biol. **2:** 79–101. *f. 1.* Mr 1927.

Rehder, A. *Pottsia grandiflora.* Jour. Arnold Arbor. **8:** 68. "Ja" 28 F 1927.

Rehder, A. *Pseudocytisus* and *Vella.* Jour. Arnold Arbor. **8:** 22–24. "Ja" 28 F 1927.

Rehder, A. The varietal categories in botanical nomenclature and their historical development. Jour. Arnold Arbor. **8:** 56–68. "Ja" 28 F 1927.

Robinson, B. L. [*Eupatorium* and *Ophryosporus*]. (in Standley, P. C. Trees and shrubs of Mexico. Contr. U. S. Natl. Herb. **23:** 1432–1470. 15 N 1926.)

Rodenhiser, H. A. Physiologic specialization of *Ustilago nuda* and *Ustilago tritici.* Phytopathology **16:** 1001–1007. *f. 1.* 15 D 1926.

Rydberg, P. A. Notes on Fabaceae—VIII. *Hamosa.* Bull. Torrey Club **54:** 13–23. "Ja" 22 F 1927.
Several species described as new.

Sande-Bakhuyzen, H. L. van de, and Alsberg, C. L. The growth curve in annual plants. Physiol. Rev. **7:** 151–187. Ja 1927.

Scarth, G. W. The influence of external osmotic pressure and of disturbance of the cell surface on the permeability of *Spirogyra* and acid dyes. Protoplasma **1:** 204–213. S 1926.

Schaffner, J. H. Sex-limited characters in heterosporous sporophytes. Ohio Jour. Sci. **27:** 19–24. "Ja" 15 F. 1927.

Scott, F. M. On certain fossil cones from the Pacific coast. Bull. Torrey Club **54:** 7–11. "Ja" 22 F 1927.

Scott, I. T. Some protein analogies of the mycelium of *Fusarium Lycopersici.* Missouri Agr. Exp. Sta. Res. Bull. 92: 1–44. *f. 1–9.* O 1926.

Seaver, F. J. A tentative scheme for the treatment of the genera of the Pezizaceae. Mycologia **19:** 86–89. 1 Mr 1927.

Seaver, F. J., and Chardon, C. E. Botany of Porto Rico and the Virgin Islands. Mycology. Sci. Survey Porto Rico **8^1:** 1–208. 29 D 1926.
Contributions by R. A. Toro, F. D. Kern, H. H. Whetzel and L. O. Overholts.

Seaver, F. J., Whetzel, H. H., and Westcott, C. Studies on Bermuda fungi. I. *Poronia leporina.* Mycologia **19:** 43–50. *f. 1–5 + pl. 1–5.* 1 Mr 1927.

Seifriz, W. The physical properties of erythrocytes. Protoplasma **1:** 345–365. *f. 1–7 + pl. 6, 7.* D 1926.

Serrano, F. B. Deterioration of abaca (Manila hemp) fiber through mold action. Philipp. Jour. Sci. **32:** 75–101. *f. 1, 2 + pl. 1–10.* Ja 1927.

Setchell, W. A. *Zostera marina latifolia:* ecad or ecotype? Bull. Torrey Club **54:** 1–6. "Ja" 22 F 1927.

Shaner, R. F. Lamarck and the evolution theory. Sci. Mo. **24**: 251–255. Mr 1927.

Shear, C. L. Mycology in relation to human pathology. Am. Nat. **61**: 151–159. Mr–Ap 1927.

Shull, G. H. A heterozygous phenotype in shepherd's purse. Hereditas **9**: 225–235. *f. 1–6.* Ja 1927.

Small, J. K. Among floral aborigines. A record of exploration in Florida in the winter of 1922. Jour. N. Y. Bot. Gard. **28**: 1–20; 25–40. *f. 1–5.* Ja, F 1927.

Sorokin, H. A study of meiosis in *Ranunculus acris.* Am. Jour. Bot. **14**: 76–84. *pl. 13–15.* "F" 8 Mr 1927.

Spaeth, C. P., and Kraybill, H. R. A biochemical study of the false-blossom disease of the cranberry. Jour. Agr. Res. **34**: 35–47. 1 Ja 1927.

Sprague, G. F. Heritable characters of maize. XXVII.—Colored scutellum. Jour. Hered. **18**: 41–44. *f. 16.* "Ja" 9 Mr 1927.

Sprague, T. A. *Alibertia* or *Cordiera.* Jour. Bot. **65**: *16–17.* Ja 1927.

Sprague, T. A. *Cerefolium* Haller. Jour. Bot. **65**: 15–16. Ja 1927.

Standley, P. C. A counterfeit collection of Mexican plants falsely attributed to Brother G. Arsene. Science II, **65**: 130–133. 4 F 1927.

Standley, P. C. Poisonous trees of Central America. Yale Univ. School For. Trop. Woods 9: 3–7. 1 Mr 1927.

Standley, P. C. *Primula Parryi.* Gard. Chron. III, **81**: 27. *f. 1.* 8 Ja 1927.

Standley, P. C. Three new species of plants collected in British Honduras by Harry W. Winzerling. Yale Univ. School For. Trop. Woods 9: 10–12. 1 Mr 1927.

Hyperbaena Winzerlingii, Banisteria heterocarpa and *Lycianthes hypoleuca.*

Stebbins, G. L. Two plants new to Mt. Katahdin. Rhodora **29**: 15–16. 28 Ja 1927.
Epilobium lactiflorum and *Draba fladnizensis.*

Stewart, G., and Tingey, D. C. A method for controlling pollination of sugar beets. Jour. Am. Soc. Agron. **19**: 126–127. F 1927.

Stout, A. B., McKee, R. H., and Schreiner, E. J. The breeding of forest trees for pulp wood. Jour. N. Y. Bot. Gard. **28**: 49–63. *f. 1–7.* Mr 1927.

Taylor, A. M. Moss habitats of the western Catskills. Bryologist **30**: 9–12. "Ja" Mr 1927.

Toro, R. A. Fungi of Santo Domingo. I. Mycologia **19**: 66–85. *pl. 6.* 1 Mr 1927.
Several species described as new.

Toro, R. A. Pseudoperisporiales (in Seaver, F. J., and Chardon, C. E. Botany of Porto Rico and the Virgin Islands. Mycology. Sci. Surv. Porto Rico. **8**: 40–41. 29 D 1926).

Twining, F. S. A western currant. Nat. Mag. **9**: 151. *illust.* Mr 1927.
Ribes glutinosum.

Wainio, E. O. Lichenes Mexicani a F.M. Liebmann annis 1841–1843 collecti, in Museo Hauniensi asservati. Dansk Bot. Arkiv. 4^{11}: 1–25. 10 F 1926.

Waldron, L. R. Hybrid selections of Marquis and Kota, a comparative study with regard to disease resistance, yield and baking quality. No. Dakota Agr. Exp. Sta. Bull. 200: 1–64. *f. 1–11.* S 1926.

Walker, J. C. Diseases of cabbage and related plants. U. S. Dept. Agr. Farmers Bull. 1439: 1–30. *f. 1–12.* F 1927.

Walker, M. N., and Stahl, C. F. Certain grass hosts of the sugar cane mosaic disease and of the corn aphid considered in relation to their occurrence in Cuba. Trop. Pl. Res. Foundation Bull. 5: 1–14. 1926.

Weatherby, C. A. *Equisetum pratense* in Berkshire County, Massachusetts. Rhodora **29**: 32. "F" 28 Ja 1927.
New Marlboro.

Weatherby, C. A. Imperfectly circinate vernation in ferns. Am. Fern. Jour. **16:** 109–111. *f. 1–3.* "D 1926" 2 F 1927.

Weber, G. F., and Ramsey, G. B. Tomato diseases in Florida. Florida Agr. Exp. Sta. Bull. 185: 61–138. *f. 58–99.* D 1926.

Weimer, J. L. Crown wart of alfalfa in the south. Phytopathology **16:** 1012. 15 D 1926.

Wherry, E. T. Observations on the woolly lipfern. Am. Fern Jour. **16:** 107–109. "D 1926" 2 F 1927.

Whetzel, H. H., and Melhus, I. E. Joseph Rosenbaum. 1887–1925. Phytopathology **16:** 895–897. *port.* 15 D 1926.

Wilson, C. L. Adventitious roots and shoots in an introduced weed. Bull. Torrey Club **54:** 35–38. *f. 1, 2.* "Ja" 22 F 1927.
Roripa austriaca

Wilson, E. H. *Juniperus procera* Hochst. Jour. Arnold Arbor. **8:** 1–2. *pl. 4.* "Ja" 28 F 1927.

Wilson, H. K., and Hottes, C. F. Wheat germination studies with particular reference to temperature and moisture relationships. Jour. Am. Soc. Agron. **19:** 181–190. *f. 1.* F 1927.

Wingard, S. A. Black end of apple. Phytopathology **16:** 1011–1012. *f. 1.* 15 D 1926.

Wylie, R. B. Leaf structure and wound response. Science II, **65:** 47–50. 21 Ja 1927.

Stimulation, toxicity, and antagonism of calcium nitrate and manganese chloride as indicated by growth of wheat roots

LELA V. BARTON AND SAM F. TRELEASE

(WITH THREE TEXT-FIGURES)

The importance of certain chemical elements, such as calcium,[1] as necessary for normal growth of higher plants has long been known, but it is only comparatively recently that detailed investigations have been made to determine the quantities of manganese, boron, and zinc that may be indispensable for normal growth of plants in general or of certain plants in particular. It was shown very early that salts of these and of many other elements may have a poisonous action upon plants, but it was also reported by various investigators that solutions containing extremely low concentrations of the salts of these and of several other elements seem to be beneficial rather than harmful to certain plants. The beneficial effects have generally been termed stimulating effects and may be expressed by the plant in various ways, such as by more rapid increase in length of tops or roots, greater luxuriance of foliage, greater dry weight, greater green weight, etc. Brenchley (1914) gives a number of interesting cases of such stimulation. A survey of the literature, however, would not warrant the generalization that every toxic substance acts as a stimulant when supplied in a sufficiently dilute solution.

The powerful effect of zinc salts in minute traces on the growth of fungi was discovered by Raulin (1869, 1870). Raulin also observed a striking effect of manganese salts, but he was doubtful whether the effect of the manganese salts was not due to traces of zinc. Richards (1897, 1899) tested a number of ele-

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[1] The ten elements whose necessity for ordinary green plants was established very early are: K, Ca, Mg, Fe, N, S, P, C, O, H. With the exception of iron, these are required in relatively large amounts, and it is easily demonstrated that green plants cannot develop if any one of these elements is not supplied.

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ments and concluded that the stimulating action of zinc in increasing the dry weight of fungi is shared with other elements, such as iron, lithium, cobalt, etc. These general results, especially with zinc, have been confirmed in a number of other investigations cited by Steinberg (1919), as well as by his own results.

A remarkable case of the effect of manganese is seen in the work of Bertrand and Javillier (1912a), who report that one part of manganese in one million of the culture solution increased slightly the dry weight of *Aspergillus*, and the effect continued to increase even up to one part in 100. In another test they found (1912b) that a combination of manganese and zinc was more effective than either alone. An extraordinary effect of zinc is reported for one experiment which showed that a definite increase in yield was produced by the addition of one part of zinc to twenty-five million parts of solution, and one part in ten millions nearly doubled the yield.

The evidence is not conclusive as to whether infinitesimal amounts of certain of these elements are absolutely indispensable to the normal physiological activity of the fungus protoplasm or whether minute traces of these elements, though non-essential, are stimulating in their action. The former view is held by Bertrand and Javillier (1912a, 1912b), who regard traces of manganese and zinc as essential for normal metabolism. Richards (1897, 1899), on the other hand, has emphasized the stimulating effects. Richards points out that stimulated cultures have a heavily matted mycelium and exhibit diminished spore production. It is possible that extremely small quantities of zinc and manganese are essential for normal growth and that slightly larger amounts give greater growth—the latter accompanied, however, by the growth modifications described by Richards. A double action of this sort is reported by Richards for iron salts.

Manganese salts, in small quantities, appear to have important beneficial effects on the growth of the higher green plants. Although larger quantities of manganese have a toxic influence on growth, recent work indicates that minute traces of this element may be essential for normal growth and maturation.

McHargue (1914) made a study of the manganese content of the seed coats of various seeds and considered that the presence of manganese in the seed coats indicated a relation of this element to the oxidizing enzymes which not only have to do with the selection, making, and storing of food in the kernel, but which may also stimulate the enzymes which break up fats, sugars, and starches, making them available as food for the young seedling.

In later papers McHargue (1919, 1922, 1923, 1924, 1925) has presented evidence, from actual cultures of plants deprived of manganese and of those supplied with traces of this element, that manganese is indispensable for the normal growth and development of ordinary green plants.

Leguminous plants were found by McHargue (1922) to be more sensitive than other plants to a lack of manganese, and he concluded that this element is apparently concerned in the assimilation of nitrogen and the synthesis of protein. He thinks that manganese plays the rôle of a necessary catalyst in plant metabolism, and that manganese, together with iron, functions in the synthesis of chlorophyll. References to the earlier literature on the effects of manganese are given in one of the papers by McHargue (1923).

Brenchley (1914) cites many investigations in which beneficial effects of manganese have been obtained with soil cultures. She also reports one experiment (Brenchley, 1910) in which barley was grown to maturity in a series of water cultures containing nutrient solutions to which manganese sulphate was added. In a later series of tests the plants were allowed to grow only seven weeks. In both cases, manganese sulphate in minute traces had a decided stimulating action on root and top growth. A discrepancy in results of the two experiments Brenchley attributed to a difference in the concentration of the nutrient salts employed and to a difference in length of growing period.

It has recently been found that a form of chlorosis of spinach and beets is associated with smaller amounts of manganese compounds in the chlorotic tissue than in the healthy tissue, and that the chlorosis could be cured by spraying a dilute solution of manganese salts on the leaves or by mixing these salts with the soil (McLean and Gilbert, 1925; Gilbert, McLean, and Hardin, 1926; Gilbert, McLean, and Adams, 1927).

A survey of the literature indicates that most of the work on the effect of manganese on the higher plants has been done with soil cultures and with solution cultures containing complex mixtures of salts. Relatively little attention has been given to the effects of dilute simple solutions of manganese salts, especially with reference to the possibility of obtaining an acceleration of growth with such solutions. The effects of single-salt solutions of manganese should be of special importance as representing conditions considerably less complex than those involved in soil cultures or in mixed solutions containing four or more nutrient salts.

Recent work has indicated that minute traces of several elements besides manganese may be essential for the growth of green plants. Somner and Lipman (1926) have furnished photographic evidence that normal growth and development of a considerable number of widely different, higher green plants did not occur when boron and zinc were excluded from the culture solution. Brenchley and Warington (1927) say that normal growth of certain plants does not occur when the culture solution lacks boron and that no other element, out of fifty-two tested, has proved capable of replacing boron. Special attention was given to manganese, the necessity of which had previously been determined.

The important effects of manganese which have been reported by various investigators emphasize the need of further detailed studies of the influence on plant growth of manganese salts, alone and in combination with other salts.

That the toxicity of manganese salts may be decreased or even eliminated altogether by addition of calcium salts, has been established. McCool (1913) investigated the toxicity of manganese salts to green plants and the antagonistic relations between salts of manganese and of other elements. In one test, in which only ten Canada field pea seedlings were used, he found that a simple solution of 0.000125 M manganese chloride was injurious and that a similar solution containing 0.00025 M manganese chloride prevented growth entirely. This test was continued for five days. In other tests with Canada field pea seedlings he found that the poisonous action of manganese salts toward the pea seedlings was greatly reduced when the usual nutrient salts were present in the culture solution, the lethal concentration of manganese chloride in the latter case being four hundred times as strong. From the results of these and other experiments, he concluded that simple solutions of manganese salts are extremely poisonous to pea and wheat seedlings, but the degree of toxicity is much lower when manganese salts are added to nutrient solutions or to soil cultures.

The injurious action of solutions of manganese salts was found by McCool (1913) to be manifested mainly toward the tops of the plants, chlorosis of the leaves being the first indication of an injurious concentration of a manganese salt. It is interesting to note that manganese salts were found to be less injurious to plants grown in the dark than to those grown in the light. Calcium, potassium, sodium, and magnesium salts were each effective in counteracting the poisonous action of a manganese salt. Mutual antagonism was observed to exist between a manganese salt and salts of each of the following elements: potassium, sodium, and magnesium. But in no case did the addition of a manganese salt to a solution of a calcium salt result in an increased development of plants over that in the corresponding simple solutions of the calcium salt.

The present paper reports experiments upon the elongation of wheat roots in simple solutions of different concentrations of manganese chloride and calcium nitrate and in mixed solutions containing combinations of the two salts in different proportions. The objects of this study were: (1) to determine whether stimulating effects could be observed in simple solutions of manganese chloride or of calcium nitrate; and (2) to determine the possible antagonistic effects of these two salts in mixed solutions.

METHOD

The method of procedure in performing each series of experiments, the results of which are given in the ensuing pages, was essentially the same as that described in papers by Trelease and Trelease (1925, 1926a, 1926b).

Large and small beakers were used, all of which were thoroughly cleaned and then rinsed in tap water, after which they were dipped in hot distilled water and hung on glass rods to dry. After drying, they were removed and again dipped in hot distilled water and replaced as before. The germinating dishes, graduated cylinders, flasks, and all other glassware, as well as forceps and scissors, were treated in the same manner.

Molecular solutions were prepared by dissolving weighed amounts of analyzed salts in water obtained from a Barnstead still. The concentrated solutions were diluted and mixed to obtain the desired concentrations and proportions.[2] In every series two cultures supplied with a three-salt standard solution and one with distilled water were used as controls. The three-salt control contained 0.02 M potassium acid phosphate, 0.02 M calcium nitrate, and 0.02 M magnesium sulphate.

The culture solutions were transferred to the beakers which had previously been prepared in the following manner: The mouths of the small beakers (300 cc. Pyrex, tall form, without spout) were covered with paraffined bobbinet, which had previously been boiled in distilled water. A paraffined linen thread was used to tie the bobbinet over the beaker. This having been done, the bobbinet was trimmed and each small beaker was placed inside a larger one (600 cc.) of the same form.

The solutions were then poured in until the small beaker was entirely filled, and the solution filled the space around it, the level being even with the top of the small beaker, so that no air bubble was left under the bobbinet. Care was taken that the level of the solution did not extend above the bobbinet. Duplicate cultures with each solution were prepared.

In the bottom of each of five glass-covered culture dishes (24 cm. in diameter) were placed sheets of filter paper, which were then moistened with distilled water. Into the dishes were scattered the wheat grains (Marquis wheat supplied by Julius Schendel, Campbell, Minn., 1924 crop), which had previously been soaked in distilled water for three hours and rinsed several times to remove foreign matter which might be present. The grains were taken individually with forceps and placed furrow side down. The dishes were left at ordinary room temperature until the primary root had attained a length of about 6 mm. (usually 24 to 28 hours).

The germinated grains were then placed on the bobbinet at the surface of the solutions, so that the primary roots dipped into the solutions. Before each grain was placed in contact with the first solution, the length of the primary root was recorded. Then a grain with a primary root of approximately the same length was placed in each of the twenty-one other cultures. This process was repeated until there were twenty-five actual measurements of primary root lengths. An average of these lengths was obtained as a measurement of the initial root length.

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[2] Volume-molecular concentrations are used in this paper, each value for concentration representing the number of gram molecules contained in each liter of solution.

The cultures were then placed in a dark chamber (described by Trelease, 1925), which was kept at approximately 19° C. During the first forty-eight hours, each culture was covered with a watch glass.

The duration of the growth period was the length of time it took the primary roots of the three-salt control to elongate about 80 mm. (from 6 mm. to 86 mm.), the period thus required being approximately 100 hours. The cultures were then removed from the incubator and observations made on the general appearance of the roots of the plants of each. The length of the primary root of each seedling was recorded. Each of the growth values given in the tables was obtained by deducting the mean initial root length from the mean final root length, and expressing this value for elongation as a percentage of the average elongation for the standard three-salt solution.

RESULTS AND DISCUSSION

Single-salt solutions

It is of special interest to note the relations between growth rates and volume-molecular concentrations of manganese chloride and calcium nitrate in single-salt solutions. These data are given in table 1 and are plotted in the graphs of figure 1. In these graphs, as well as those of figures 2 and 3, the ordinates represent elongation expressed as a percentage of that for the three-salt standard solution, and the abscissas represent concentration (plotted on a logarithmic scale, except the zero concentration).

Stimulation of growth by simple solutions of manganese chloride. It will be noticed from the graph of figure 1 that there was in the case of manganese chloride a marked stimulation of growth in certain concentrations. Wheat roots grown in 0.00001 M manganese chloride show an elongation of over forty per cent greater than that attained by roots in distilled water. This amounts to eight per cent greater elongation than that of the roots in the three-salt standard solution. In somewhat higher concentrations of this salt, as 0.00005 M and 0.00008 M, the elongation continues to be more rapid than in distilled water, but it is less rapid than in the standard solution. More concentrated solutions than these, however, cause the growth curve to drop very quickly, until 0.005 M allows only about three per cent of the growth for distilled water.

TABLE I

Growth of wheat roots in single-salt solutions of manganese chloride and of calcium nitrate; growth values are expressed as percentage of growth for the three-salt standard solution[1]

VOLUME-MOLECULAR CONCENTRATION, M	MANGANESE CHLORIDE			CALCIUM NITRATE			
	A	B	Average	A	B	C	Average
0	—	77[2]	75[3]	82[2]	68[2]	84[2]	75[3]
0.0000001	—	—	—	79	76	81	79
0.000001	—	—	—	79	69	74	74
0.00001	103	112	108	86	82	84	84
0.00005	94	83	89	—	—	—	—
0.00008	83	78	81	—	—	—	—
0.0001	—	—	—	84	61	69	71
0.000126	34	38	36	—	—	—	—
0.0002	25	22	24	—	—	—	—
0.00032	15	14	15	—	—	—	—
0.0005	7	11	9	—	—	—	—
0.0008	5	7	6	—	—	—	—
0.005	2	2	2	—	—	—	—
0.001	—	—	—	54	45	58	52
0.01	—	—	—	35	35	37	36
0.1	—	—	—	27	20	22	23

[1] Each value is the average of duplicate cultures of 25 seedlings. Thus the final average for manganese chloride represents 100 seedlings; that for calcium nitrate, 150 seedlings.

[2] Value obtained in this particular series.

[3] Average for all distilled water cultures (25 seedlings each): 76, 76, 74, 69, 81, 78, 67, 65, 72, 72, 77, 84, 65, 66, 76, 88, 97, 94, 76, 76, 67, 67, 61, 66, 83, 86.

The results secured in the present experiments appear to offer conclusive evidence that simple solutions of manganese chloride have a very pronounced effect in stimulating root elongation. They serve therefore to extend the earlier observations which showed stimulating action on older plants growing in soil cultures or in mixed nutrient solutions (Brenchley, 1910; Loew and

Sawa, 1902; Aso, 1902). The presence of nutrient salts in the culture solution is apparently not essential to the growth-accelerating effect of manganese.

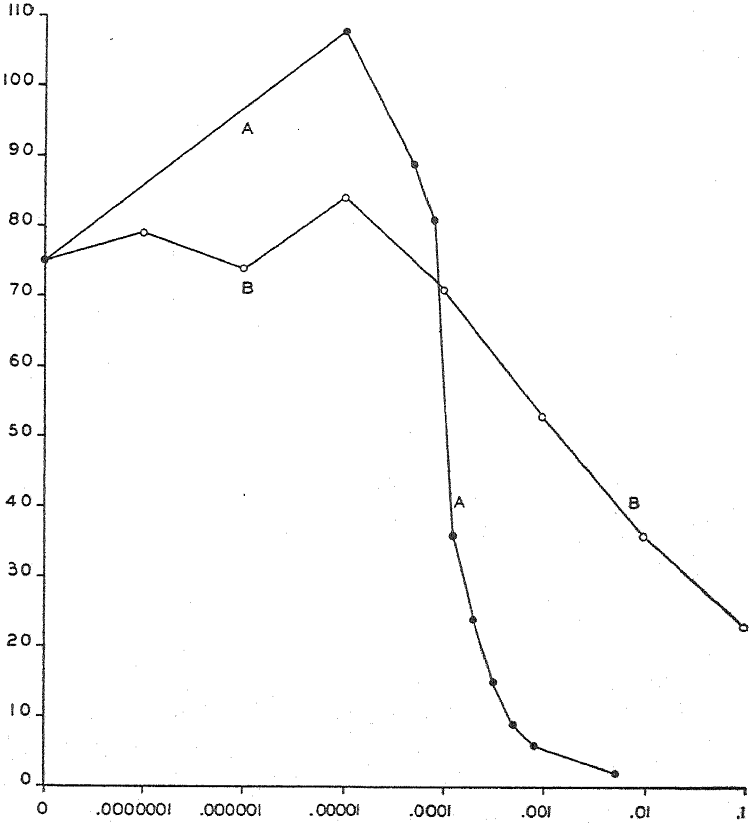

FIG. 1. Growth of wheat roots in single-salt solutions of manganese chloride (*A*) and of calcium nitrate (*B*).

Ordinates represent elongation as percentage of elongation for three-salt standard solution. Abscissas represent volume-molecular concentration (logarithmic scale, except the zero concentration).

Growth in simple solutions of calcium nitrate. The graph for calcium nitrate (figure 1) is very different from that for manganese chloride, since it exhibits no pronounced rise indicative of stimulation. There is a suggestion, however, that certain concentrations of calcium nitrate may possibly allow slightly more rapid elongation than distilled water. Further study would be needed to obtain conclusive evidence on this point, since the observed effect is so small that it may lie within the limits of the experimental error. In no case did a single-salt solution of calcium nitrate prove a better medium for root elongation than the three-salt standard solution.

It will be noticed from the data in table 1 that there was considerable variation in the results obtained in the three tests which were made with calcium nitrate single-salt solutions. This may have been due to differences in the quality of the distilled water used in the tests. The great difficulty of preparing distilled water of uniform quality has of course been repeatedly emphasized in the literature (Hibbard, 1915; Scarth, 1924). The presence of minute quantities of antagonizing or retarding substances may alter the rate of absorption of calcium nitrate by the roots, or the distilled water may excercise a separate toxic influence.

Theories regarding stimulation. Clear distinctions between stimulants and nutrient materials are not yet possible. Brenchley (1914) states two main theories which are held to account for stimulating effects: (1) That the stimulants act as catalytic agents, being valueless on their own account, but valuable in that they aid in procuring essential food substances; (2) that the stimulants themselves are of integral value for nutrition. In either case, a particular stimulant may be essential for normal growth of a certain plant form. In order to prove that a certain element is indispensable for any plant form, it must of course be shown not only that this element is necessary for normal development but also that no other element can replace it. The work of Brenchley and Warington (1927) on boron is especially convincing, since fifty-two other elements were tested and none was capable of replacing boron.

The effect of manganese in accelerating the rate of root elongation in very young seedlings may be quite different in nature from that which may render this element necessary for normal growth and maturation of green plants. At least, salts of certain elements known to be essential (calcium, potassium, and magnesium) may lack such stimulating action on root growth; simple solutions of the salts of these elements have generally been found to allow less rapid growth than distilled water (Trelease and Trelease, 1926a).

TABLE 2

Growth of wheat roots in nine series of mixed solutions containing manganese chloride and calcium nitrate; growth values represent each of the duplicate cultures, and are expressed as percentage of growth for the three-salt standard solution[1]

VOLUME-MOLECULAR CONCENTRATION OF CALCIUM NITRATE, M	VOLUME-MOLECULAR CONCENTRATION OF MANGANESE CHLORIDE, M																	
	0.00001		0.00005		0.00008		0.000126		0.0002		0.00032		0.0005		0.0008		0.005	
	1a	1b	2a	2b	3a	3b	4a	4b	5a	5b	6a	6b	7a	7b	8a	8b	9a	9b
0	105	100	97	92	82	84	28	41	25	26	19	11	4	10	5	5	2	2
0.0000001	99	102	94	94	76	80	54	47	15	20	9	14	4	8	5	5	1	2
0.000001	102	93	85	88	76	78	58	59	52	50	11	15	7	7	6	5	2	2
0.00001	88	98	70	70	64	64	64	58	52	52	46	52	41	40	12	14	3	2
0.0001	92	86	59	62	47	40	47	51	43	43	45	47	47	52	50	48	16	16
0.001	52	59	54	55	56	59	49	51	43	45	41	43	34	37	39	35	27	29
0.01	38	40	35	35	37	42	45	42	40	43	39	39	37	33	41	42	25	26
0.1	29	29	29	31	29	29	28	29	26	28	30	33	28	31	31	26	15	16

[1] Each value represents 25 seedlings.

What some investigators have called stimulation might in certain cases be regarded as due to an antagonism to toxic substances in the distilled water used. For example, Scarth (1924) found that *Spirogyra* lived only from 5 to 20 hours in pure distilled water condensed in silica or platinum and having a pH value of about 5.5; however, the addition to the water of a suitable concentration of any one of many single salts greatly extended the duration of life—to as many as 528 hours in some cases. This extension of the life period he attributed to an antagonistic action of the salt to the toxicity of the water, the latter toxicity resulting, he says, from the hydrogen-ion concentration due to dissolved carbon dioxide. However, the acceleration of root growth in dilute solutions of manganese chloride can hardly be ascribed to antagonism of substances already present in the distilled water; for calcium nitrate, which has generally been found to be one of the most effective antagonizing substances, gave little or no evidence of growth acceleration, while manganese chloride—which usually has only a slight antagonistic action—gave a striking acceleration of growth.

Two-salt solutions

The data pertaining to root elongation in mixed solutions containing manganese chloride and calcium nitrate are given in tables 2 and 3 and are shown graphically in figures 2 and 3. In each of the nine series of cultures the manganese chloride content was held constant and the calcium nitrate was varied from zero to 0.1 M. The growth occurring in a solution of manganese chloride alone is shown by the first point in each curve, and the growth in simple solutions of calcium nitrate of the concentrations used in the mixed solutions is shown by a separate curve. The figures therefore show clearly (1) the growth in every mixed solution, (2) the growth in the corresponding simple solution of manganese chloride, and (3) the growth in the corresponding simple solution of calcium nitrate.

TABLE 3

Growth of wheat roots in nine series of mixed solutions containing manganese chloride and calcium nitrate; growth values represent the fifty seedlings in the duplicate cultures, and are expressed as percentage of growth for the three-salt standard solution[1]

VOLUME-MOLECULAR CONCENTRATION OF CALCIUM NITRATE, M	VOLUME-MOLECULAR CONCENTRATION OF MANGANESE CHLORIDE, M								
	0.00001	0.00005	0.00008	0.000126	0.0002	0.00032	0.0005	0.0008	0.005
0	*103*	*94*	*83*	34	25	15	7	5	2
0.0000001	101	*94*	78	50	18	11	6	5	2
0.000001	98	86	77	58	51	13	7	6	2
0.00001	93	70	64	*61*	*52*	*49*	40	13	3
0.0001	89	60	44	49	43	47	*49*	*49*	16
0.001	56	55	57	50	44	42	36	37	*28*
0.01	39	35	39	43	41	39	35	42	26
0.1	29	30	29	29	27	31	30	29	15

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[1] The maximum in each vertical column is italicized.

Comparing the graphs of figure 2 with those of figure 3, it is seen that the form of the growth curves undergoes a distinct change as the concentration of manganese chloride becomes lower. The curves for the series containing the six highest concentrations of manganese chloride (figure 3) rise to a maximum value and then fall. Those for the three lowest concentrations (figure 2) have an entirely different form, since they fall continuously in passing from left to right.

Antagonism as indicated by diminished toxicity of manganese chloride. For the mixtures containing the six highest concentrations of manganese chloride (figure 3) it seems safe to consider that antagonism is shown in the usual way. Since each of these curves rises as the concentration of calcium nitrate increases, it appears to be reasonable to interpret this rise as due to the effect of calcium nitrate in antagonizing the toxicity of manganese chloride (Osterhout, 1918; McCool, 1913; Hawkins, 1913; Stiles and Jörgensen, 1914). This effect is clearly shown in each of the six curves. If, for each series, the increased growth due to antagonism is divided by the growth in the corresponding manganese solution, it will be noted that the greatest antagonism, by this criterion, occurs in the solutions in which manganese chloride is most concentrated.

The curve for calcium nitrate (dotted line) lies in general much higher than those for the mixtures. Mixtures having relatively high concentrations of calcium nitrate, however, gave slightly better growth than the corresponding simple solutions of calcium nitrate.

Antagonism as indicated by diminished stimulation by manganese chloride. For the mixtures containing the lowest concentrations of manganese chloride (figure 2), antagonism is not so readily defined. These mixtures contain concentrations of manganese chloride that in simple solution would stimulate root growth, in the sense that they would allow more rapid root growth than occurs in distilled water. And for these concentrations of manganese chloride the addition of successively higher concentrations of calcium nitrate decreases rather than increases growth. Thus the calcium nitrate appears to interfere with the stimulating effect of the manganese chloride, possibly by making the small amount of manganese chloride unavailable for use by the roots. Antagonism appears to be shown by an inhibition of the stimulating effect that low concentrations of manganese chloride would exhibit in simple solution. It will be observed that in four of the mixed solutions containing 0.00001 M manganese chloride and in two of those with 0.00005 M manganese chloride, the growth is more rapid than in the corresponding calcium nitrate solutions (dotted line).

Quantitative measurement of antagonism. It is evident that an exact quantitative measurement of antagonism can only be obtained when it is possible to estimate the total toxicity that the two-salt solutions would have if neither salt influenced the

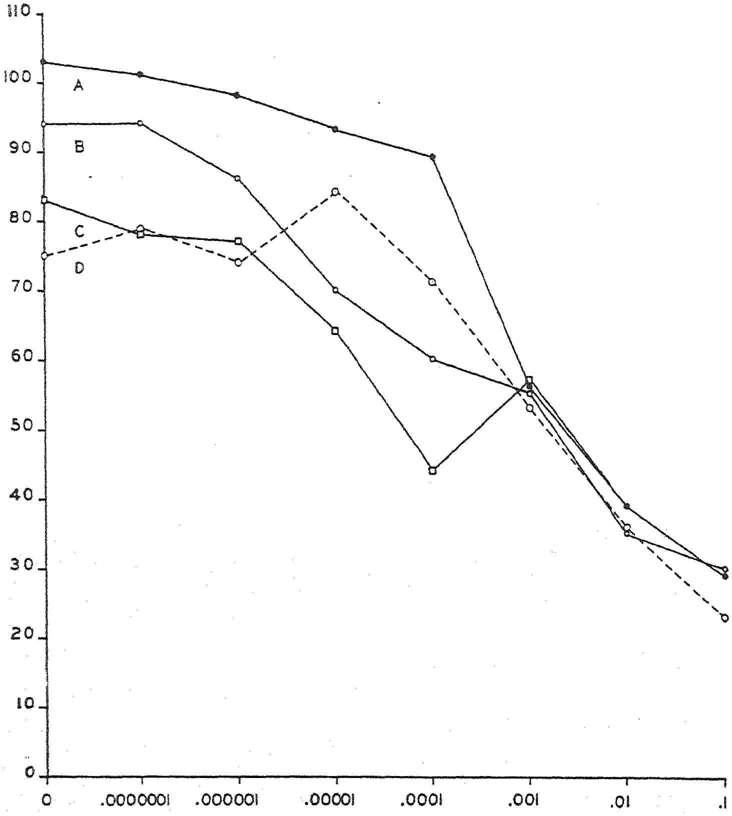

FIG. 2. Growth of wheat roots in two-salt solutions of manganese chloride and calcium nitrate.

Ordinates represent elongation as percentage of that for three-salt standard solution. Volume-molecular concentrations of calcium nitrate are shown by the abscissas (logarithmic scale, except the zero). *A* represents mixed solutions containing 0.00001 M manganese chloride; *B*, 0.00005 M; *C*, 0.00008 M. *D* (dotted line) shows growth in single-salt solutions of calcium nitrate. In each series the concentration of manganese chloride remained constant while that of calcium nitrate varied in the manner shown by the abscissas.

toxicity of the other salt. How this additive effect may be estimated has been shown by Osterhout (1914a, 1914b, 1915, 1918, 1922). The fundamental assumption necessary here is that the effect of one salt can be expressed in terms of the other salt. This can be done if the curves for growth in simple solutions have nearly the same slope when a logarithmic scale is used for concentrations (Trelease and Trelease, 1926a). It seems inadvisable to attempt to estimate additive effects if the

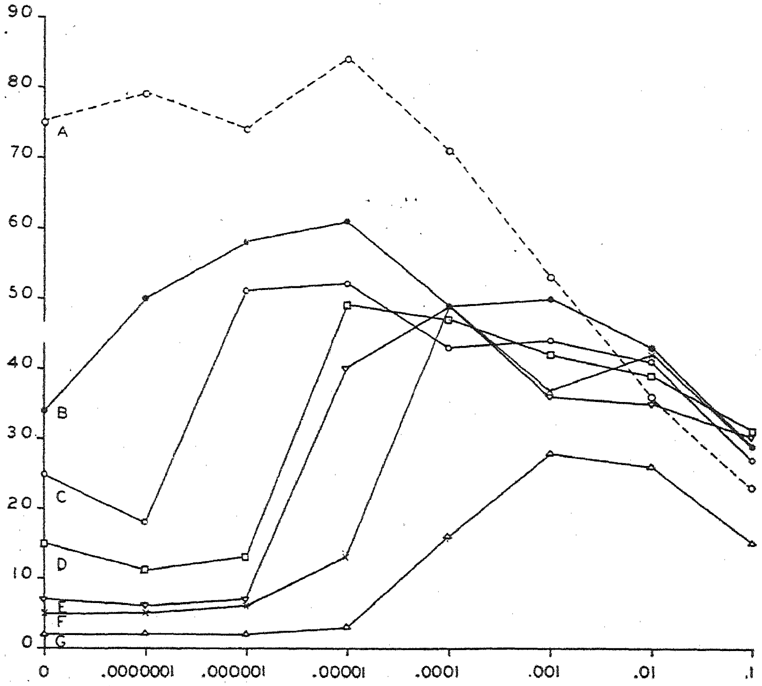

FIG. 3. Growth of wheat roots in two-salt solutions of manganese chloride and calcium nitrate.

Ordinates represent elongation as percentage of that for three-salt standard solution. Volume-molecular concentrations of calcium nitrate are shown by the abscissas (logarithmic scale, except the zero). *A* (dotted line) shows growth in single-salt solutions of calcium nitrate. *B* represents mixed solutions containing 0.000126 M manganese chloride; *C*, 0.0002 M; *D*, 0.00032 M; *E*, 0.0005 M; *F*, 0.0008 M; *G*, 0.005 M. In each series the concentration of manganese chloride remained constant while that of calcium nitrate varied in the manner shown by the abscissas.

curves differ in slope as much as do those for manganese chloride and calcium nitrate (see figure 1).

Molecular ratios of manganese chloride to calcium nitrate. The ratios of manganese chloride to calcium nitrate, especially those ratios allowing greatest root elongation, as shown in table 4, furnish interesting data when examined in connection with the growth curves of figures 2 and 3. For the three lowest concentrations of manganese chloride best growth was secured in each case with the highest of the tested ratios of manganese chloride to calcium nitrate (100, 500, and 800 molecules of manganese chloride to 1 of calcium nitrate). For the six highest concentrations of manganese chloride the corresponding ratios for optimum growth are much lower—12.6, 20, 32, 5, 8, 5. Comparing these two groups, it appears that to secure optimum growth with the high concentrations of manganese chloride the ratio of calcium nitrate to manganese chloride must be relatively very high.

TABLE 4

Values of the ratio of manganese chloride to calcium nitrate for the nine series of mixed solutions[1]

VOLUME-MOLECULAR CONCENTRATION OF CALCIUM NITRATE, M	VOLUME-MOLECULAR CONCENTRATION OF MANGANESE CHLORIDE, M								
	0.00001	0.00005	0.00008	0.000126	0.0002	0.00032	0.0005	0.0008	0.005
0.0000001	*100*	*500*	*800*	1260	2000	3200	5000	8000	50,000
0.000001	10	50	80	126	200	320	500	800	5,000
0.00001	1	5	8	*12.6*	*20*	*32*	50	80	500
0.0001	0.1	0.5	0.8	1.26	2	3.2	*5*	*8*	50
0.001	0.01	0.05	0.08	0.126	0.2	0.32	0.5	0.8	*5*
0.01	0.001	0.005	0.008	0.0126	0.02	0.032	0.05	0.08	0.5
0.1	0.0001	0.0005	0.0008	0.00126	0.002	0.0032	0.005	0.008	0.05

[1] The maximum value in each vertical column is italicized.

A progressive change in the optimum proportions does not persist, however, within the series having the six highest concentrations of manganese chloride; for within these series the ratios for optimum growth (12.6, 20, 32, 5, 8, 5) agree as nearly as possible, considering the great differences in values of the consecutive ratios that were tested. A further, detailed study would be needed before very precise statements could be made concerning optimum proportions of manganese chloride to calcium nitrate.

It is of interest to observe in figures 2 and 3 the minimum concentration of calcium nitrate that appeared to have a decided effect on each of the growth curves, and to note in table 4 the corresponding molecular ratios. This examination shows that one molecule of calcium nitrate to every fifty or one hundred molecules of manganese chloride may be expected to have a distinct influence upon the way in which the manganese chloride affects the plants.

Appearance of roots. Throughout the experiments the appearance of the roots grown in both single-salt and two-salt solutions indicated that each salt has a specific toxic effect. In response to the toxicity of manganese chloride, brown rings or splotches appeared on the very brittle roots. Often there was a series of brown rings distributed at rather regular intervals along the root and separated by apparently healthy tissue. It is difficult to explain why the toxic effects should be localized in this manner.

Calcium nitrate, in the highest concentrations, caused the formation of bands of transparent material on each side of the root and extending from the base to within one or two millimeters of the tip. In calcium nitrate solutions favoring rapid elongation, the roots became somewhat attenuated and very tender and provided with dense masses of root hairs.

SUMMARY

A study was made of the elongation of the primary root of wheat seedlings in single-salt solutions of manganese chloride and calcium nitrate, and in solutions containing both of these salts.

Manganese chloride, in simple solution of proper concentration, had a very pronounced stimulating effect on the root elongation of very young wheat seedlings.

Calcium nitrate, in dilute solution, did not appear to have a significant stimulating effect; it allowed about the same elongation as occurred in distilled water. At high concentrations calcium nitrate was found to be far less toxic than manganese chloride.

When growth in single-salt solutions is plotted against logarithms of concentrations, the slope of the graph for calcium nitrate is markedly different from that of the graph for manganese chloride; hence equally toxic solutions of these salts do not remain equally toxic when diluted to the same degree.

Calcium nitrate had a marked effect in reducing the toxicity that higher concentrations of manganese chloride showed in simple solution, and it also reduced the stimulating effect that low concentrations of manganese chloride exhibited in simple solution.

The effect of calcium nitrate in diminishing the toxic action of manganese chloride appears to be much more pronounced than the effect of manganese chloride on the toxicity of calcium nitrate.

Differences in appearance of roots grown in single-salt solutions indicating specific toxicity were observed. The symptoms of poisoning by manganese chloride are especially interesting, since these are characterized by brown rings distributed at rather regular intervals on the root.

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Literature cited

Aso, K. 1902. On the physiological influence of manganese compounds on plants. Bull. Coll. Agric. Tokyo **5:** 177–185.

Bertrand, G., and M. Javillier. 1912a. Action du manganèse sur le développement de l'*Aspergillus niger*. Bull. Soc. Chim. France 4: **11:** 212–221.

————. 1912b. Action combinée du manganèse et du zinc sur le développement et la composition minérale de l'*Aspergillus niger*. Bull. Soc. Chim. France 4: **11:** 347–353.

Brenchley, Winifred E. 1910. The influence of copper sulphate and manganese sulphate upon the growth of barley. Ann. Bot. **24:** 571–583.

————. 1914. Inorganic plant poisons and stimulants. Cambridge.

————**, and K. Warington.** 1927. The rôle of boron in the growth of plants. Ann. Bot. **41:** 167–187.

Gilbert, B. E., F. T. McLean, and W. L. Adams. 1927. The current mineral nutrient content of the plant solution as an index of metabolic limiting conditions. Plant Physiol. **2:** 139–151.

————**, F. T. McLean, and L. J. Hardin.** 1926. The relation of manganese and iron to a lime-induced chlorosis. Soil Sci. **22:** 437–446.

Hawkins, L. A. 1913. The influence of calcium, magnesium, and potassium nitrates upon the toxicity of certain heavy metals toward fungus spores. Physiol. Res. **1:** 57–92.

Hibbard, R. P. 1915. The question of the toxicity of distilled water. Amer. Jour. Bot. **2:** 389–401.

Loew, O., and S. Sawa. 1902. On the action of manganese compounds on plants. Bull. Coll. Agric. Tokyo **5:** 161–172.

McCool, M. M. 1913. The action of certain nutrient and non-nutrient bases on plant growth. Cornell Univ. Agric. Exp. Sta. Memoir **2:** 113–215.

McHargue, J. S. 1914. The occurrence and significance of manganese in the seed coat of various seeds. Jour. Amer. Chem. Soc. **36:** 2532–2536.

————. 1919. The effect of manganese on the growth of wheat; a source of manganese for industrial purposes. Jour. Indus. Eng. Chem. **11:** 332–353.

McHargue, J. S. 1922. The rôle of manganese in plants. Jour. Amer. Chem. Soc. **44:** 1592–1598.

————. 1923. The effect of different concentrations of manganese sulphate on the growth of plants in acid and neutral soils and the necessity of manganese as a plant nutrient. Jour. Agric. Res. **24:** 781–794.

————. 1924. The association of manganese with vitamines. Jour. Agric. Res. **27:** 417–424.

————. 1925. The occurrence of copper, manganese, zinc, nickel, and cobalt in soils, plants, and animals and their possible functions as vital factors. Jour. Agric. Res. **30:** 193–196.

McLean, F. T., and B. E. Gilbert. 1925. Manganese as a cure for a chlorosis of spinach. Science **61:** 636–637.

Osterhout, W. J. V. 1914a. Quantitative criteria of antagonism. Bot. Gaz. **58:** 178–186.

————. 1914b. The forms of antagonism curves as affected by concentration. Bot. Gaz. **58:** 367–371.

————. 1915. The determination of additive effects. Bot. Gaz. **60:** 228–234.

————. 1918. The basis of measurement of antagonism. Jour. Biol. Chem. **34:** 363–368.

————. 1922. Injury, recovery, and death in relation to conductivity and permeability. 295 p., 96 fig. Philadelphia and London: J. B. Lippincott Co.

Raulin, Jules. 1869. Études chimiques sur la végétation. Ann. Sci. Nat. Bot. 5: **11:** 93–299.

————. 1870. Sur les conditions chimiques de la vie des organismes inferieurs. Compt. Rend. **70:** 634–638.

Richards, H. M. 1897. Die Beeinflussung des Wachstums einiger Pilze durch chemische Reize. Jahrb. Wiss. Bot. **30:** 665–688.

————. 1899. The effect of chemical irritation on the economic coefficient of sugar. Bull. Torrey Bot. Club **26:** 463–479.

Scarth, G. W. 1924. The toxic action of distilled water and its antagonism by cations. Trans. Roy. Soc. Canada **18:** 97–104.

Somner, A. L., and C. B. Lipman. 1926. Evidence on the indispensable nature of zinc and boron for higher green plants. Plant Physiol. **1:** 231–249.

Steinberg, R. A. 1919. A study of some factors in the chemical stimulation of the growth of *Aspergillus niger*. Amer. Jour. Bot. **6:** 330–356.

Stiles, W., and I. Jörgensen. 1914. The antagonism between ions in the absorption of salts by plants. New Phytologist **13:** 253–268.

Trelease, S. F. 1925. Chamber with thermostatic control and rotating table for plant cultures. Bull. Torrey Bot. Club **52:** 389–395.

————**, and H. M. Trelease.** 1925. Growth of wheat roots in salt solutions containing essential ions. Bot. Gaz. **80:** 74–83.

————**, and H. M. Trelease.** 1926a. Toxicity and antagonism in salt solutions as indicated by growth of wheat roots. Bull. Torrey Bot. Club **53:** 137–156.

————**, and H. M. Trelease.** 1926b. Relation of temperature to the physiological values of salt solutions as indicated by the growth of wheat roots. Bull. Torrey Bot. Club **53:** 605–609.

Magnolia cordata and other woody plants

W. W. Ashe

MAGNOLIA CORDATA Michx.[1] For more than one hundred years after this tree was collected by Michaux and through him introduced into cultivation it was unknown in a wild state. Its rediscovery in 1913 by Mr. L. A. Berckmans in eastern Georgia growing near one of the localities from which originally reported by Michaux gives hope that *Gordonia altamaha* may eventually be found also. The magnolia was later reported by Berckmans from localities in middle Georgia. During the summer of 1926, it was found by the writer along Bear Creek, about 12 miles southeast of Tuscaloosa, Tuscaloosa County, Alabama, associated with *M. acuminata*, the oaks and hickories. It was also found, more abundant and of larger size, up to 70 feet tall, upon sandy soils, in hollows, and along small streams tributary to Kintabush and Yantley creeks, Choctaw County, Ala. Since these streams head in Mississippi, within 20 miles of where *M. cordata* is very abundant, it and also *Quercus arkansana* var. *caput-rivuli*, referred to below, should be looked for in that state in the hilly sandy region which lies to the west and south of Meridian.

Greene proposed three species of *Polycodium* from Florida—*P. caesium*,[2] *P. revolutum*[2] and *P. oliganthum*.[3] He noted that the bracts of all were often foliaceous, that consequently some of the flowers seemed axillary, and that the flowers were scattered over the plants in place of being largely clustered upon branches which seemed almost naked on account of the small size of the bracts. Dr. J. Nieuwland has furnished me such excellent descriptions of Greene's type specimens as to give me assurance that certain other sheets of the same collections bearing the same numbers as Greene's type sheets represent the same forms. Each of Greene's plants has thick leaves pubescent upon both faces and densely glaucous beneath. In middle peninsular Florida, there occurs a *Polycodium* the leaves of which are invariably green beneath, but it is associated with one (*P. oliganthum* Greene) with smaller and more pointed leaves which are consistently glaucous beneath. Both as a rule have foliaceous bracts, black fruit maturing in mid-summer and scattered over the plant, in place of being clustered on branchlets which are largely destitute of leaves, and leaves pubescent on both surfaces —characters common to certain species of the pine region of the southeastern coast. The plant with the leaves green beneath grows in the hammocks; the other is restricted to the high sandy pine woods and the "scrub." A description of this plant follows:

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[1] Fl. Bor.-Am. 1: 328. 1803.

[2] Pittonia 3: 249. 1897.

[3] Leaflets Bot. Obs. 2: 226. 1912.

Polycodium quercinum sp. nov. A shrub 1–1.5 m. high. Leaves rather thin, rounded or obtuse at the apex, oval, obovate or elliptic, 2.5–4.5 cm. long, 1–2 cm. wide, mostly rounded at the narrowed base, rarely subcordate, the margin ciliate, and sometimes slightly revolute, especially after midsummer on exposed or dry sites, above dark green and sparingly pubescent with short spreading hairs, beneath yellowish green, and with short spreading grayish pubescence over the entire lower surface as well as on the short petiole. Twigs slender, pubescent with short spreading, often matted, hairs. Flowers, appearing about the middle of April, small, about 4 mm. long with acute divisions to the corolla, from the axils of the leaf-like bracts on slender, nodding, rarely 1 cm.–long pubescent pedicels. Fruit black or dark purple-black, glossy, 7–12 mm. thick, not large for the genus, sparingly pubescent.

Type: Abundant in hammocks near Lynne, Marion County, Florida, W. W. A. April 1923, July 1926.

FRAXINUS CATAWBIENSIS Ashe.[4] On account of the infrequency of its occurrence in middle North Carolina, the region from which originally reported, it was eventually assumed that this ash was a hybrid, although it was not possible with accuracy to fix its parentage. In recent years, however, it has been noted frequently in the foothills region of northeastern Georgia. Its characters seem well fixed. Specimens of *Fraxinus profunda* Bush or *F. biltmoreana* Bead., species which might be considered as one of the parents, are not known to occur in this immediate region. It seems desirable to regard it as an infrequent and rather local species related to *F. profunda* by its slightly flattened seed, but lacking its large calyx; resembling *F. biltmoreana* in its pubescence and in the pale often glaucescent

[4] Bot. Gaz. 33: 230. 1902.

lower surface of the foliage, but lacking its stout terete seed; approaching *F. americana* in the general shape of its fruit and in the pale lower surface of the leaflets, but separated by the velvety and persistent pubescence on the twigs, and the slightly flattened and not terete body to the seed. It has been noted as far south as Dawsonville (5 miles south, on the Atlanta road), Dawson County, Georgia, and seems to be more abundant in Rabun, White and Habersham Counties, Georgia, than elsewhere.

× **Schmaltzia Ashei** hyb. nov. *S. Ashei* Small, Fl. S. U. S. Ed. 1. 729. *Rhus caroliniana* Ashe, Bot. Gaz. **20**: 548. 1895. This species was based upon herbarium specimens collected from wild plants. Later it was cultivated. Seedlings from these cultivated plants varied greatly, some approaching *S. glabra* (L.) Small and others *S. Michauxii* (Sarg.) Small. It is believed that it is a hybrid between these plants and should be dropped as a species.

QUERCUS ARKANSANA CAPUT-RIVULI Ashe.[5] During the summer of 1926, specimens of this local tree were noted in Bibb County, Ala., at and near Woodfin Tucker's store; in Hale County, Ala., near Havana; in Tuscaloosa County, Ala., along the highway north of Moundsville and about eight miles south of Tuscaloosa, growing in each case upon sandy banks near small water courses. Two trees at Woodfin Tucker's store, probably planted, were 16 and 18 inches in diameter, 45 and 50 feet high, respectively. The deliquescence of the prominent veins near the margin of the leaf and consequent prevailing absence of awns was characteristic of the leaves in each of these localities, just as it is in trees growing in West Florida and Georgia.

PADUS CUTHBERTII Small. This well marked species, which has heretofore been reported only from the vicinity of Augusta, Georgia, was found (W. W. A., 1923, 1926) growing around stream heads at Crestview and Mossyhead, West Florida.

In connection with the pubescent summer shoots of certain species of *Tilia* which have glabrous spring shoots, it may be of interest to note that many summer shoots of *Tilia heterophylla* and its varieties were collected during the summer of 1926 in Georgia, and Alabama. These were all glabrous, thus confirming previous observations upon the summer shoots of this species.

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[5] Jour. Elisha Mitchell Soc. **40**: 44. Aug. 1924.

CASTANEA MARGARETTA forma **Dormonae** form. nov. This is a rare form which occurs in middle Louisiana, having three large nuts to the involucre in place of one. If this form occurred within the distribution of chestnut it would doubtless be regarded as a hybrid or as having a chestnut strain. Chestnut is not known to occur, however, within 350 miles of Natchitoches Parish, Louisiana, the station for this form, which was collected there by Miss Caroline Dormon. In its long pubescent twigs, and the densely set and elongated spines on the fruit, this form approaches variety *arcuata* Ashe of the Gulf Coast of Louisiana and the "Big Thicket" region of Texas.

× **Hicoria ludoviciana** hyb. nov. *H. aquatica* (Michx. f.) Brit. × *H. Buckleyi* var. *arkansana* (Sarg.) Ashe. This interesting hybrid, which has been collected and studied by Miss Caroline Dormon, of Natchitoches Parish, Louisiana, where it is found, has the foliage, buds, bark and general aspect of *H. Buckleyi*. The fruit, however, is compressed, the husk very thin, the nut wrinkled, particularly at the base, the shell though not brittle, so thin that it can be crushed between the fingers, and the very large kernel is much wrinkled and bitter.

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Kieffer pear seedlings and fire blight resistance

H. E. THOMAS

The Kieffer pear is a hybrid between the oriental pear (*Pyrus serotina* var. *culta* Rehder) and the European species (*P. communis* var. *sativa* Linn.), presumably the variety Bartlett. The latter parent represents the more desirable fruit characters of the European pear, and the former exhibits a high degree of resistance to the fire blight disease caused by *Erwinia amylovora* (Burrill) Comm. S.A.B. Kieffer is intermediate between its parents in fruit quality and blight resistance. Since fire blight is still an important limiting factor in the cultivation of the pear, it has seemed desirable to make further selections from hybrids of the Kieffer type. This somewhat heterodox method was adopted because of its obvious advantage in quickly placing a relatively large number of individuals under experiment. Accordingly, a considerable quantity of Kieffer seed was obtained in 1921 from open-pollinated trees on the University farm at Ithaca, N. Y. These were planted in April, 1921; and in 1924, 774 seedlings had survived the hazards of transplanting, rodents, and low temperatures.

A further departure from the usual fruit breeding practice was then made in an effort, by repeated inoculation, to eliminate at an early age those individuals which were susceptible to blight. Thus it will be necessary to bring only a small part of the original population up to fruiting age. During the seasons of 1924, 1925, and 1926, all the seedlings were inoculated at least five times with the fire blight organism. Many of them received ten or more inoculations. Cultures were used from both pear and apple and from widely separated localities. In August, 1924, 177 of the 774 trees were blighted. In October, 1926, 368 of the 679 remaining trees had become more or less affected.[1] These figures are by no means final, since infection is closely related to fluctuating growth conditions of the trees. For example, from the records of 1924 in parts of rows on poorer soil, 6, 9, and 10 per cent of the trees were infected, while in parts of the same rows a few rods distant but in better soil, 20, 25, and 26 per cent of the trees were blighted.

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[1] Four arbitrary classes of resistance were set up. Class O was completely resistant; class 1, blight checked within the current season's growth; class 2 was killed back to the second year growth; in class 3 the organism had penetrated into the wood of preceding seasons frequently killing the entire trees.

In the records given above classes 1, 2, and 3 are included in the blighted group, while in table 1, classes 0 and 1 are contrasted with the relatively susceptible classes 2 and 3.

The seedlings showed an extremely wide variation in most of the characters which were examined. The question then arose as to whether there existed any parallel between blight resistance and external characters of the tree. A preliminary examination of the form, color and other characters of the various parts of the tree disclosed no striking parallel between resistance and any of the characters studied. However, several of the more definite characters when examined in greater detail were found to be more frequently associated with resistance than were their corresponding characters (see table 1). The relation

TABLE 1

Some tree characters associated with resistance to fire blight

CHARACTER		RESISTANT	SUSCEPTIBLE	RATIO
Branchlets	Stout	107	58	100 : 54
	Slender	80	117	100 : 146
Color of branches 2–4 years old	Red to reddish brown	73	38	100 : 52
	Green to grayish green	69	74	100 : 107
Spininess	Spiny	147	147	100 : 100
	Smooth	37	30	100 : 81
Lenticel size	Large	12	16	100 : 133
	Small	24	35	100 : 145
Leaf breadth in relation to length	Broad	123	114	100 : 92
	Narrow	43	48	100 : 111
Leaf serration	Deep	21	26	100 : 123
	Not deep	61	47	100 : 77

is not assumed to be other than an accidental parallel and is not sufficiently constant to provide any notable aid in selection for resistance. It is interesting, however, that the character associated with greater resistance may be one rather of the susceptible than of the resistant parent. This is true of the reddish color of bark, this character being among those most frequently associated with resistance. On the other hand, the spiny character of the susceptible parent is found quite as often in the resistant as in the susceptible class. Support is thus given to the expectation that resistant individuals of this population may show the desirable tree and fruit characters of the *P. communis* parent.

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INDEX TO AMERICAN BOTANICAL LITERATURE
1920–1927

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Addoms, R. M. Toxicity as evidenced by changes in the protoplasmic structure of root hairs of wheat. Am. Jour. Bot. **14**: 147–165. *pl. 17, 18.* 22 Mr 1927.

Anderson, D. B. A microchemical study of the structure and development of flax fibers. Am. Jour. Bot. **14**: 187–211. *pl. 19–22.* 22 Mr 1927.

Anderson, E. *Iris versicolor* in northern Ontario. Bull. Am. Iris Soc. 22: 47–48. Ja 1927.

Anderson, R. J., Nabenhauer, F. P., and Shriner, R. L. The distribution of dihydrositosterol in plant fats. Jour. Biol. Chem. **71**: 389–399. Ja 1927.

Anderson, R. J., and Shriner, R. L. The reduction products of certain plant sterols. Jour. Biol. Chem. **71**: 401–406. Ja 1927.

Andrews, F. M. A sylvan prophecy. Am. For. & For. Life **33**: 299. *illust.* My 1927.

Appleman, C. O., and Conrad, C. M. Pectic constitutents of peaches and their relation to softening of the fruit. Maryland Agr. Exp. Sta. Bull. 283: 1–8. Jl 1926.

Armitage, E. Notes on Amazonian vegetation. Jour. Roy. Hort. Soc. **52**: 40–45. *f. 42-44.* Ja 1927.

Ashby, S. F. Bacterial wilt disease of bananas. Kew Bull. Misc. Inf. **1927**: 14–18. *pl. 4–6.* Ja 1927.

Barkley, G. Differentiation of vascular bundle of *Trichosanthes anguina.* Bot. Gaz. **83**: 173–184. *pl. 8.* 21 Ap 1927.

Benedict, R. C. Is the distribution and naturalization of the hart's tongue scientifically defensible? Am. Fern. Jour. **17**: 19–23. 30 Mr 1927.

Bennett, A. Notes on *Potamogeton*. Jour. Bot. **65**: 113–118. Ap 1927.

Berry, E. W. The Baltic amber deposits. Sci. Mo. **24**: 268–278. Mr 1927.

Berry, E. W. New plant records from the Pleistocene. Torreya **27**: 21–27. *pl. 1.* 14 Ap 1927.

Bisby, G. R., Conners, I. L., and Bailey, D. L. The parasitic fungi found in Manitoba. Bull. Dept. Agr. Canada 71: 77–83. 1926.

Bixby, W. G. Northern nuts—varieties. Rept. Proc. No. Nut Grow. Assoc. **17**: 44–57. S 1926.

Blake, M. A. Apples of New Jersey. N. J. Agr. Exp. Sta. Ext. Bull. 62: 1–15. *6 col. pl.* 1 F 1927.

Blake, S. F. The section *Diplostephioides* of *Aplopappus*. Am. Jour. Bot. **14**: 107–115. 22 Mr 1927.

Many species described as new.

Bliss, S. H. Another Vermont station for the male fern. Am. Fern Jour. **17**: 27. 30 Mr 1927.

East Calais.

Bowers, C. G. Rhododendrons and azaleas for breeding purposes in America. Jour. N. Y. Bot. Gard. **28**: 81–86. Ap 1927.

Boyce, J. S. Observations on white pine blister rust in Great Britain and Denmark. Jour. For. **24**: 893–896. D 1926.

Boyer, C. S. Synopsis of North American Diatomaceae. I. *Coscinodiscatae*, *Rhizoselenatae*, *Biddulphiatae*, *Fragilariatae*. Proc. Acad. Nat. Sci. Phila. **78** (suppl): 1–228. 1927.

Brewbaker, H. E. Studies of self-fertilization in rye. Minnesota Agr. Exp. Sta. Tech. Bull. 40: 1–40. *f. 1–9* + *pl. 1.* Je 1926.

Brink, R. A., and Abegg, F. A. A laboratory method of preparing starch from maize seed. Plant Physiol. **2**: 101–102. Ja 1927.

Brink, R. A., and Burnham, C. R. Nucleus and cytoplasm in relation to differential pollen-tube growth. Proc. Natl. Acad. Sci. **13**: 238–242. 15 Ap 1927.

Brooks, M. The "Massachusetts fern" in West Virginia. Am. Fern Jour. **17**: 26. 30 Mr 1927.
Thelypteris simulata.

Brown, P. E., and Erdman, L. W. Inoculation of legumes. Iowa Agr. Exp. Sta. Circ. 102: 1–8. Mr 1927.

Buchholz, J. T., and Blakeslee, A. F. Abnormalities in pollen-tube growth in *Datura* due to the gene "tricarpel." Proc. Natl. Acad. Sci. **13**: 242–249. *f. 1–12.* 15 Ap 1927.

Buchholz, J. T., and Palmer, E. J. Supplement to the catalogue of Arkansas plants. Trans. Acad. Sci. St. Louis **25**: 91–155. *pl. 6–13.* Je 1926.
Supplement to "List of Arkansas Plants," by Branner and Coville.

Burk, D. Does the pea plant fix atmospheric nitrogen? Plant Physiol. **2**: 83–90. Ja 1927.

Burns, G. P., and Burns, G. R. Studies in tolerance of New England trees. V. Relation of the moisture content of the soil to the sensitiveness of the chloroplast to light. VI. A portable instrument for measuring solar radiation in forests. Vermont Agr. Exp. Sta. Bull. 257: 1–16. *f. 1–8.* S 1926; 261: 1–30. *f. 1–10.* F 1927.

Capinin, J. M. An aberrant rosal (*Gardenia florida* L.) flower of seminal origin. Philipp. Agr. **15**: 557–558. *pl. 1.* F 1927.

Caron, O. Quelques observations sur la photomicrographie. Sci. Agr. **7**: 312–315. *f. 1–4.* Ap 1927.

Chardon, C. E., and Toro, R. A. Plant disease notes from the central Andes. Phytopathology **17**: 147–153. *f. 1.* 15 Mr 1927.

Chesebrough, M. A. A study of Mexican *Riccia*. Bot. Gaz. **83**: 99–102. *f. 1–6.* 23 Mr 1927.

Christensen, C. *Athyrium Wardii* in North America? Am. Fern Jour. **17:** 23–24. 30 Mr 1927.

Christensen, J. J. Physiologic specialization and parasitism of *Helminthosporium sativum.* Minnesota Agr. Exp. Sta. Tech. Bull. 37: 1–101. *pl. 1–12.* Jl 1926.

Clayton, E. E. *Diplodia* ear-rot disease of corn. Jour. Agr. Res. **34:** 357–371. 15 F 1927.

Clements, F. E. Wild flowers of the west. Nat. Geog. Mag. **51:** 566–622. *col. pl. 1.* My 1927.

Clements, F. E., and Showalter, W. J. The family tree of the flowers. Nat. Geog. Mag. **51:** 555–563. [*col. pl.*] My 1927.

Clute, W. N. Relatives of the onion. Am. Bot. **33:** 49–50. *illust.* Ap 1927.

Cockerell, T. D. A. A journey in South America. Nat. Hist. **27:** 77–92. Ja–F 1927.

Coleman, L. C. Structure of spore wall in *Ganoderma.* Bot. Gaz. **83:** 48–61. *pl. 5.* 23 Mr 1927.

Colley, R. H., and Taylor, M. W. *Peridermium kurilense* Diet. on *Pinus pumila* Poll., and *Peridermium indicum* n.sp. on *Pinus excelsa* Wall. Jour. Agr. Res. **34:** 327–330. *f. 1.* 15 F 1927.

Collins, G. N., and Kempton, J. H. Variability in the linkage of two seed characters of maize. U. S. Dept. Agr. Bull. 1468: 1–64. *f. 1–5.* Mr 1927.

Coward, K. H. The influence of light and heat on the formation of vitamine A in plant tissue. Jour. Biol. Chem. **72:** 781–799. Ap 1927.

Dearness, J. An annotated list of Anthracnoses in the genera *Gloeosporium, Colletotrichum, Marssonia, Septogloeum, Cylindrosporium,* of the Melanconiales. Bull. Dept. Agr. Canada 71: 62–76. 1926.

Decker, C. E. New leaf fossils from the Permian of central Oklohoma. Proc. Oklohoma Acad. Sci. **6:** 263–264. Ja 1927.

Decker, C. E. Some new fossil algal horizons in the Arbuckle Mountains. Proc. Oklohoma Acad. Sci. **6:** 260–262. Ja 1927.

Douglass, A. E. Solar records in tree growth. Science II. **65:** 220–221. 4 Mr 1927.

Drechsler, C. Two water molds causing tomato rootlet injury. Jour. Agr. Res. **34:** 287–296. *f. 1, 2.* 1 F 1927.

Durland, W. D. Chicle—source of chewing gum. Am. For. & For. Life **33:** 228–229, 247. *illust.* Ap 1927.

East, E. M. Inheritance of trimorphism in *Lythrum salicaria.* Proc. Natl. Acad. Sci. **13:** 122–124. 15 Mr 1927.

Eaton, F. M. The water requirement and cell-sap concentration of Australian saltbush and wheat as related to the salinity of the soil. Am. Jour. Bot. **14:** 212–226. *f. 1, 2 + pl. 23.* 26 Ap 1927.

Exell, A. W. William Bartram and the genus *Asimina* in North America. Jour. Bot. **65:** 65–69. *pl. 581.* Mr 1927.

Ezekiel, W. N. Fruit-rotting Sclerotinias. III. Longevity of buried brown-rot mummies. Maryland Agr. Exp. Sta. Bull. 284: 1–22. *f. 1–3.* O 1926.

Fairchild, D. The fascination of making a plant hybrid; being a detailed account of the hybridization of *Actinidia arguta* and *Actinidia chinensis.* Jour. Hered. **18:** 49–62. *f. 1–7.* "F" 11 Ap 1927.

Farquhar, F. P. Vagaries of the Big Trees. Am. For. & For. Life **33:** 259–263, 296–297. *illust.* My 1927.

Farwell, O. A. The botanical identity of ma huang. Jour. Am. Pharm. Assoc. **16:** 135–136. F 1927.

Folsom, D. Uniformity of nomenclature for the viroses of *Solanum tuberosum.* Phytopathology **17:** 161–165. 15 Mr 1927.

Fuller, A. M. Botanical collecting, 1925. Yearbook Publ. Mus. Milwaukee **5:** 76–82. *f. 98, 99.* "1925." 1926.

Galloway, B. T. Plant introduction as applied to blight-resistant chestnuts and related crops. Rep. Proc. North. Nut Grow. Assoc. **17**: 58–62. S 1926.

Gardner, M. W. Apple blotch canker eradication. Phytopathology **17**: 185–188. 15 Mr 1927.

Gardner, N. L. New species of *Gelidium* on the Pacific coast of North America. Univ. Calif. Publ. Bot. **13**: 273–318. *pl. 36–54.* 17 Mr 1927.

Gates, F. C., Woollett, E. C., and Breakey, E. P. Distribution and abundance of *Spartina Michauxiana* at Douglas Lake, Cheboygan County, Michigan. Bot. Gaz. **83**: 185–193. *f. 1, 2.* 21 Ap 1927.

Gates, R. R. Two new species of *Oenothera*. Canad. Field Nat. **41**: 23–27. *illust.* F 1927.
O. agari and *O. eriensis.*

Goldstein, B. An *Empusa* disease of *Drosophila*. Mycologia **19**: 97–109. *pl. 8–10.* 1 My 1927.

Goodspeed, T. H., and Clausen, R. E. Interspecific hybridization in *Nicotiana*. V. Cytological features of two F_1 hybrids made with *Nicotiana Bigelovii* as a parent. Univ. Calif. Publ. Bot. **11**: 117–125. *f. 1–8.* 17 Mr 1927.

Graves, A. H. Forms and functions of leaves. Brooklyn Bot. Gard. Leafl. **14**$^{9-10}$: 1–8. 10 N 1926.

Graves, E. W. *Botrychium dissectum* in Iowa. Am. Fern Jour. **17**: 15–18. 30 Mr 1927.

Greaves, J. E. The microflora and the productivity of leached and non-leached alkali soil. Soil Sci. **23**: 271–302. Ap 1927.

Greene, R. A., and Stout, A. B. A report on sterility in sixty-five dwarf-bearded irises. Bull. Am. Iris Soc. **22**: 40–43. *illust.* Ja 1927.

Griffiths, D. The regal lily. U. S. Dept. Agr. Bull. 1459: 1–19. *f. 1–4.* D 1926.

Haas, A. R. C. Effect of reaction of solution on growth of alfalfa. Bot. Gaz. **83**: 207–211. *f. 1–3.* 21 Ap 1927.

Haas, A. R. C., and Reed, H. S. Relation of dessicating winds to fluctuation in ash content of citrus leaves and phenomenon of mottle-leaf. Bot. Gaz. **83**: 161–172. *f. 1–3.* 21 Ap 1927.

Haas, A. R. C., and Reed, H. S. Significance of trace of elements not ordinarily added to culture solutions, for growth of young orange trees. Bot. Gaz. **83**: 77–84. *f. 1–6.* 23 Mr 1927.

Hansen, H. H. Control of internal rot of caprified figs. Phytopathology **17**: 199–200. 15 Mr 1927.

Heath, F. M. In defense of the mullein. Am. Bot. **33**: 62–65. Ap 1927.

Heimlich, L. F. Microsporogenesis in the cucumber. Proc. Natl. Acad. Sci. **13**: 113–115. 15 Mr 1927.

Heppner, M. J. Further evidence on the factor for bitterness in the sweet almond. Genetics **11**: 605–606. 22 Ap 1927.

Herbert, P. A. A laboratory study of black spruce. Jour. For. **25**: 437–442. Ap 1927.

Hibbard, R. P. Negative results on physiological balance in soil cultures. Plant Physiol. **2**: 1–38. *f. 1–11.* Ja 1927.

Hunter, L. M. Comparative study of spermogonia of rusts of *Abies.* Bot. Gaz. **83**: 1–23. *f. 1, 2 + pl. 1–4.* 23 Mr 1927.

Huskins, C. L. The elimination of false wild oats; a breeding possibility. Sci. Agr. **7**: 285–286. Ap 1927.

Huskins, C. L. Some Russian impressions. Sci. Agr. **7**: 300–305. Ap 1927.

Hutchinson, J. Contributions toward a phylogenetic classification of flowering plants: VI. (A) The genera of Hydrageaceae. (B) The genera of Saxifragaceae, by J. E. Dandy. Kew Bull. Misc. Inf. **1927**: 100–118. 1927.

Ichijima, K. Cytological and genetic studies on *Fragaria.* Genetics **11**: 590–604. *pl. 1–3.* 22 Ap 1927.

Inamdar, R. S., and Shrivastava, A. L. Seasonal variation in specific conductivity of wood in tropical plants with reference to leaf fall. Bot. Gaz. **83**: 24–47. *f. 1–7.* 23 Mr 1927.

Jeffrey, E. C. Conifers and the coal question. Science II. **65**: 256–257. 8 Ap 1927.

Jochems, S. C. J. The occurrence of *Blakeslea trispora* Thaxter in the Dutch East Indies. Phytopathology **17**: 181–184. *f. 1.* 15 Mr 1927.

Jodidi, S. L. The nitrogen compounds of the rice kernel as compared with those of other cereals. Jour. Agr. Res. **34**: 309–325. 15 F 1927.

Kahlenberg, L., and Traxler, R. On the passage of boric acid and certain salts into fruits and vegetables. Plant Physiol. **2**: 39–54. Ja 1927.

Kamm, M. W. Ebony spleenwort in a well. Am. Fern Jour. **17**: 26. 30 Mr 1927.

Kauffman, E. Speeding up the poplar; interesting experiments in selective breeding and hybridization that may open a secret door to more rapid wood production. Am. For. & For. Life **33**: 269–271. *illust.* My 1927.

Keefe, A. M. A new species of *Aphanocapsa.* Rhodora **29**: 39–41. "Mr" 8 Ap 1927.
A. Lewisii.

Kelley, A. P. Dune formation by pine barren plants. Bot. Gaz. **83**: 89–93. *f. 1, 2.* 23 Mr 1927.

Kendrick, J. B. *Holcus* bacterial spot of *Zea mays* and *Holcus* species. Iowa Agr. Exp. Sta. Res. Bull. 100: 303–334. *f. 1–5.* N 1926.

Kienholz, R. Shrinkage and growth in plant stems. Bot. Gaz. **83**: 103–105. 23 Mr 1927.

Kiesselbach, T. A. The immediate effect of gametic relationship and of parental type upon the kernel weight of corn. Nebraska Agr. Exp. Sta. Res. Bull. 33: 1–69. *f. 1.* D 1926.

Kiesselbach, T. A., and Anderson, A. Alfalfa investigations. Nebraska Agr. Exp. Sta. Res. Bull. 36: 1–125. *f. 1–19.* D 1926.

Kiesselbach, T. A., and Peltier, G. L. The differential reaction of strains within a variety of wheat to physiologic forms of *Puccinia graminis Tritici.* Nebraska Agr. Exp. Sta. Res. Bull. 39: 1–15. *f. 1.* D 1926.

Killip, E. P. New names for tropical American plants. Proc. Biol. Soc. Washington **40**: 29. 5 Mr 1927.

Kitson, L. C. The resurrection plants. Am. For. & For. Life **33**: 215. *illust.* Ap 1927.

Kostoff, D. Pollen-tube growth in *Lythrum Salicaria.* Proc. Natl. Acad. Sci. **13**: 253–255. *f. 1.* 15 Ap 1927.

Leach, J. G. The nature of seed-piece transmission of potato blackleg. Phytopathology **17**: 155–160. *f. 1–4.* 15 Mr 1927.

Leukel, R. W., Dickson, J. G., and Johnson, A. G. Experiments with dusts for controlling stripe disease of barley. Phytopathology **17**: 175–179. 15 Mr 1927.

Link, G. K. K., and Sharp, C. G. Correlation of host and serological specificity of *Bacterium campestre*, *Bacterium flaccumfaciens*, *Bacterium Phaseoli*, and *Bacterium Phaseoli sojense.* Bot. Gaz. **83**: 145–160. 21 Ap 1927.

Lohman, M. L. Occurrence of mycorrhiza in Iowa forest plants. Univ. Iowa Stud. Nat. Hist. **11**: 33–58. *pl. 1–8.* 1 S 1926.

Loomis, H. F. Development of flowers and bolls of Pima and Acala cotton in relation to branching. U. S. Dept. Agr. Bull. 1365: 1–28. *f. 1.* Mr 1927.

Lott, R. V. Correlation of chemical composition with hardiness in brambles. Missouri Agr. Exp. Sta. Res. Bull. 95: 1–22. *f. 1–4.* D 1926.

McCully, A. Western skunk cabbage. Am. For. & For. Life **33**: 154. *illust.* Mr 1927.
Lysichiton kamtschatcense.

MacDougal, D. T., and Overton, J. B. Sap flow and pressure in trees. Science II. **65**: 189–190. 18 F 1927.

MacMillan, H. G., and Christensen, A. A study of potato seed treatment for *Rhizoctonia* control. Wyoming Agr. Exp. Sta. Bull. 152: 57–67. Mr 1927.

McWhorter, F. P. Fungicidal value of oil sprays. Phytopathology **17**: 201–202. 15 Mr 1927.

Mack, W. B. The action of ethylene in accelerating the blanching of celery. Plant Physiol. **2**: 103. Ja 1927.

Martin, W. H. Plant diseases of New Jersey. (Thirteenth instalment.) Seed-borne diseases of potatoes: their control. New Jersey Agr. **9**^{4}: 6–7. Ap 1927.

Millar, C. E. Studies of the removal of nutrients from subsoil by alfalfa. Soil Sci. **23**: 261–267. *pl. 1.* Ap 1927.

Miyoshi, M. The preservation of natural monuments in Japan. Jour. Hered. **18**: 33–40. *f. 11–15.* "Ja" 9 Mr 1927.

Moore, F. B., and Stout, A. B. Sterility in *Apogon* and *Pogoniris.* Bull. Am. Iris Soc. **21**: 3–20. *illust.* O 1926.

Moore, G. T., and LaGarde, R. V. L. The identification of pollen from so-called "hay-fever plants." Ann. Missouri Bot. Gard. **13**: 355–390. N 1927.

Mousley, H. The genus *Amesia* in North America. Canad. Field Nat. **41**: 1–6, 28–31. *illust.* F 1927.

Murrill, W. A. Bladderwort and spatter dock. Am. Bot. **33**: 51–54. Ap 1927.

Murrill, W. A. The yellow-gilled *Russula.* Mycologia **19**: 151–152. 1 My 1927.

Nelson, J. C. M. W. Gorman. Rhodora **29**: 33–36. *port.* "Mr" 8 Ap 1927.
Born 10 N 1853. Died 7 O 1926.

Newton, R., and Martin, W. M. Apparatus for continuous dialysis at low temperature. Plant Physiol. **2**: 99. *f. 1.* Ja 1927.

Nightingale, G. T. The chemical composition of plants in relation to photoperiodic changes. Wisconsin Agr. Exp. Sta. Res. Bull. 74: 1–68. *f. 1–24.* F 1927.

Pearl, R. On the distribution of differences in vitality among individuals. Am. Nat. **61**: 113–131. *f. 1–4.* Mr-Ap 1927.

Includes accounts of experiments with *Cucumis melo.*

Peattie, D. C. Fasciation in plants. Am. Bot. **33**: 60–62. Ap 1927.

Peckham, E. A. S. 1926 bibliography of Iris literature. Bull. Am. Iris Soc. 22: 32–39. Ja 1927.

Pittier, H. El estudio de los productos forestales en Venezuela. Bol. Ci. Tecn. Mus. Com. Venezuela **1**: 3–44. 1927.

Porsild, A. E. Contributions to the flora of west Greenland. Meddel. Grønland **58**: 159–196. "1920" 1926.

Porsild, M. P., and Porsild, A. E. The flora of Disko Island and the adjacent coast of west Greenland. Meddel. Grønland **58**: 1–155. "1920" 1926.

Potter, D. A laboratory manual for general botany. 2 vols. 1–145. *pl. 1–59.* 1927.

Prát, S. Antagonistic salt action in relation to the swelling and dyeing of powdered agar. Am. Jour. Bot. **14**: 167–186. 26 Ap 1927.

Prát, S. The toxicity of tissue juices for cells of the tissue. Am. Jour. Bot. **14**: 120–125. 22 Mr 1927.

Purpus, J. A. Mexikanische Kleinorchideen. Gartenfl. **76**: 5–7, 53–54. *illust.* Ja-F 1927.

Quinn, E. J., Burtis, M. P., and Milner, E. W. Quantitative studies of vitamins A, B, and C in green plant tissues other than leaves. Jour. Biol. Chem. **72**: 557–563. Ap 1927.

Quisenberry, K. S. Chromosome numbers in buckwheat species. Bot. Gaz. **83**: 86–88. *f. 1–7 + pl. 6.* 23 Mr 1927.

Quisumbing, E. The occurrence of lactiferous vessels in the mature bark of *Hevea brasiliensis.* Univ. Calif. Publ. Bot. **13**: 319–332. *pl. 55–58.* 22 Mr 1927.

Ranker, E. R. Determination of total nitrogen, nitrate-nitrogen, and total nitrogen not including nitrate-nitrogen: further observations on a modification of the official salicyclic-thiosulphate method. Ann. Missouri Bot. Gard. **13**: 391–424. *f. 1–3.* "N 1926" Mr 1927.

Ransier, H. E. The uninterrupted life of an interrupted fern. Am. Fern Jour. **17**: 27–28. 30 Mr 1927.

Reinking, O. A., and Wollenweber, H. W. Tropical *Fusaria.* Philipp. Jour. Sci. **32**: 103–273. *f. 1–47 + pl. 1–6.* F 1927.

Rice, M. A. The haustoria of certain rusts and the relation between host and pathogene. Bull. Torrey Club **54**: 63–154. *pl. 1–9.* "F" 14 Ap 1927.

Riley, L. A. M. New species from Panama, Coiba and Cocos Islands. Bull. Misc. Inf. **1927**: 119–127. 1927.

In *Odontocarya, Elsota, Erythrochiton, Eugenia, Alibertia, Psychotria, Rauwolfia, Cordia, Solanum* and *Acalypha.*

Robinson, T. R. An orange chimera. Jour. Hered. **18**: 48. *frontispiece.* "F" 11 Ap 1927.

Robinson, W. O. The determination of organic matter in soils by means of hydrogen peroxide. Jour. Agr. Res. **34**: 339–356. 15 F 1927.

Round, E. C. Correlation of coal floras in Henry County, Missouri, and the Narragansett Basin. Bot. Gaz. **83**: 61–69. *f. 1–3.* 23 Mr 1927.

Rudolfs, W. Influence of salt upon growth rate of Asparagus. Bot. Gaz. **83**: 94–98. *f. 1, 2.* 23 Mr 1927.

Saint-Yves, A. Contribution à l'étude des *Festuca* (subgenus *Eufestuca*) de l'Amerique du nord et du Mexico. Candollea **2**: 229–316. *illust.* 1926.

Sampaio, A. J. de. Bibliographia botanica interessando o estudo da flora Brasileira. Bol. Mus. Nac. Rio de Janeiro **2**^{3}: 35–62. S 1926.

Sampaio, A. J. de. Technica da colheita de material botanico no littoral do Brazil. Bol. Mus. Nac. Rio de Janeiro **2**^{3}: 63–82. *f. 1–3.* S 1926.

Sanford, G. B. Important soil-borne diseases of crops in western Canada. Sci. Agr. **7**: 292–294. Ap 1927.

Santos, J. K. A pharmacognostical study of *Datura alba* Nees and *Datura fastuosa* Linnaeus from the Philippines. Philipp. Jour. Sci. **32**: 275–296. *pl. 1–7.* Mr 1927.

Satina, S., and Blakeslee, A. F. Further studies on biochemical differences between sexes in plants. Proc. Natl. Acad. Sci. **13**: 115–122. 15 Mr 1927.

Schaffner, J. H. Ginkgo, a flowerless seed plant. Am. Jour. Bot. **14**: 126–128. *f. 1–7.* 22 Mr 1927.

Schneiderhan, F. J. Frank J. Piemeisel. 1891–1925. Phytopathology **17**: 135–136. *port.* 15 Mr 1927.

Seaver, F. J. Cocoa and chocolate. Jour. N. Y. Bot. Gard. **28**: 86–89. Ap 1927.
Abstract of a lecture.

Shape, P. F. Stem and leaf structure of aspen at different altitudes in Colorado. Am. Jour. Bot. **14**: 116–119. *pl. 16.* 22 Mr 1927.

Sharp, C. G. Virulence, serological, and other physiological studies of *Bacterium flaccumfaciens*, *Bacterium Phaseoli*, and *Bacterium Phaseoli sojense.* Bot. Gaz. **83**: 113–144. *f. 1–8 + pl. 7.* 21 Ap 1927.

Shear, C. L. Mycology in relation to human pathology. Am. Nat. **61**: 151–159. Mr–Ap 1927.

Sherbakoff, C. D. A modified method of delinting cotton seed with sulphuric acid. Phytopathology **17**: 189–193. 15 Mr 1927.

Sherbakoff, C. D. Photographing living conidia mounted on agar. Phytopathology **17**: 195–198. *f. 1.* 15 Mr 1927.

Small, J. K. *Iris flexicaulis. Iris fulva. Iris prismatica. Iris pseudacorus. Iris rivularis. Iris Shrevei. Iris tripetala. Iris vinicolor.* Addisonia **12**: 1–16. *pl. 385–392.* 31 Mr 1927.

Small, J. K. A new gopher-berry from the Gulf states. Torreya **27**: 35–36. 14 Ap 1927.
Gaylussacia Mosieri.

Smith, C. P. A distributional catalogue of the lupines of Oregon. Contr. Dudley Herb. Stanford Univ. **1**: 1–55. 10 Mr 1927.

Smith, F. F. Some cytological studies of mosaic diseases and leaf variations. Ann. Missouri Bot. Gard. **13**: 425–484. *f. 1–4 + pl. 13–16.* "N 1926" Mr 1927.

Smith, H. B. Annual versus biennial growth habit and its inheritance in *Melilotus alba.* Am. Jour. Bot. **14**: 129–146. *f. 1–8.* 22 Mr 1927.

Smith, J. R. Some observations with reference to nut bearing trees in distant lands. Rept. Proc. North. Nut Grow. Assoc. **17**: 72–76. S 1926.

Sparrow, F. K., Jr. Occurrence of *Pythium gracile* in the United States. Rhodora **29**: 37–39. "Mr" 8 Ap 1927.

Sprague, T. A., and Sandwith, N. Y. New species of *Strychnos* from tropical America. Kew Bull. Misc. Inf. **1927**: 127–133. 1927.

Stancliff, J. O. Spring north and south. Am. Bot. **33**: 65–67. Ap 1927.

Standley, P. C. *Alfaroa,* a new genus of trees of the family Juglandaceae from Costa Rica. Jour. Washington Acad. Sci. **17**: 77–79. 19 F 1927.
A. costaricensis, described as new.

Standley, P. C. Ferns of Barro Colorado Island. I. Am. Fern Jour. **17**: 1–8. 30 Mr 1927.

Standley, P. C. New plants from Central America. VII. Jour. Washington Acad. Sci. **17**: 159–171. 4 Ap 1927.

Stapf, O. Ma huang of Chili. Kew Bull. Misc. Inf. **1927**: 133–134. 1927.

Sudworth, G. B. A new western birch. Am. For. & For. Life **33**: 286–287. *illust.* My 1927.
Betula Guthriei.

Swingle, C. F. Graft hybrids in plants. Jour. Hered. **18:** 73–94. *f. 9–14.* "F" 11 Ap 1927.

Taylor, A. M. Some ecological habitats in the Longleaf Pine Flats of Louisiana. Bull. Torrey Club **54:** 155–171. *f. 1–3.* "F" 14 Ap 1927.

Taylor, N. Walking with an object. Forty wild flowers worth hunting. Torreya **27:** 29–35. 14 Ap 1927.

Tehon, L. R., and Daniels, E. Y. Notes on the parasitic fungi of Illinois. III. Mycologia **19:** 110–129. *pl. 11.* 1 My 1927.

Many species described as new.

Thomas, W. Nitrogenous metabolism of *Pyrus malus* L. I. Influence of temperature of dessication on water-soluble nitrogenous constituents and separation of water-soluble protein from non-protein constituents. II. The distribution of nitrogen in the insoluble cytoplasmic proteins. Plant Physiol. **2:** 55–70. Ja 1927.

Thone, F. Evaporation rates in a north Florida hammock. Bot. Gaz. **83:** 70–76. *f. 1–3.* 23 Mr 1927.

Thornton, H. G., and Fisher, R. A. On the existence of daily changes in the bacterial numbers in American soil. Soil Sci. **23:** 253–259. *f. 1–4.* Ap 1927.

Tiffany, L. H. New species and varieties of Chlorophyceae. Bot. Gaz. **83:** 202–206. *pl. 9.* 21 Ap 1927.

In *Spirogyra* and *Oedogonium.*

Tisdale, W. H., Leighty, C. E., and Boerner, E. G. A study of the distribution of *Tilletia Tritici* and *T. laevis* in 1926. Phytopathology **17:** 167–174. *f. 1.* 15 Mr 1927.

Torrey, R. Nature trails at walking club camps. Torreya **27:** 27–29. Ap 1927.

Uphof, J. C. T. The botanical garden of the Pan-Pacific Research Institute in Honolulu to stimulate botanical research among the Pan-Pacific nations. Jour. Pan-Pacific Res. Inst. **2^2:** 10–11. 14 Ap 1927.

Veihmeyer, F. J., and Hendrickson, A. H. Soil-moisture conditions in relation to plant growth. Plant Physiol. **2:** 71–82. *f. 1–6.* Ja 1927.

Wann, F. B., and Hopkins, E. F. Further studies on growth of *Chlorella* as affected by hydrogen-ion concentration. Bot. Gaz. **83:** 194–201. *f. 1–3.* 21 Ap 1927.

Weir, J. R. The problem of *Dichrostachys nutans*, a weed tree in Cuba with remarks on its pathology. Phytopathology **17:** 137–146. *f. 1–4 + pl. 6–8.* 15 Mr 1927.

Wherry, E. T. The soil reactions of some saprophytic orchids. Jour. Washington Acad. Sci. **17:** 35–38. *illust.* Ja 1927.

White, R. P. Studies on tomato wilt caused by *Fusarium Lycopersici* Sacc. Jour. Agr. Res. **34:** 197–239. *f. 1–9 + pl. 1–8.* 1 F 1927.

Willaman, J. J. The determination of polysaccharides. Plant Physiol. **2:** 91–97. Ja 1927.

Wilson, E. H. Brooms and their kindred. House & Gard. **51:** 96, 97, 178, 180, 182. *illust.* Mr 1927.

Winston, J. R., Bowman, J. J., and Bach, W. J. Citrus melanose and its control. U. S. Dept. Agr. Bull. 1474: 1–63. *f. 1–17.* Mr 1927.

Winters, G. The Iowa species of *Russula*. Univ. Iowa Stud. Nat. Hist. **11:** 5–29. *pl. 1.* 1 S 1926.

Woodward, N. P. The date-palm as a ruderal plant in Massachusetts. Rhodora **29:** 51–52. "Mr" 8 Ap 1927.

Zeller, S. M. Contributions to our knowledge of Oregon fungi —II. Mycological notes for 1925. Mycologia **19:** 130–143. *f. 1–4.* 1 My 1927.

Zeller, S. M. A correction. Mycologia **19:** 150–151. 1 My 1927.

Ascospora Rubi (Westend.) Zeller, comb. nov.

Zimmerman, G. A. The chestnut blight. Rep. Proc. North. Nut Growers Assoc. **17:** 63–71. S 1926.

Studies on the flora of northern South America—X[1]

H. A. GLEASON

MISCELLANEOUS NEW OR NOTEWORTHY SPECIES

DICHAEA GRAMINOIDES (Sw.) Lindl. The history of this species extends back to 1788, when Olof Swartz published a twelve-word description of *Epidendrum graminoides* from Jamaica. The description offers nothing by which we may accurately distinguish the species today, but his citation of the locality is important. In 1799 he transferred his species to the genus *Cymbidium*. Maintaining it in this genus in his *Flora Indiae Occidentalis* in 1806, he then specified its range more exactly, as on trees in the temperate region of the mountains of southern Jamaica. His posthumous *Adnotationes Botanicae* provided a crude illustration of it in 1829. Under one or the other of these two genera the species appears in a few contemporary publications. It was transferred to the genus *Isochilus* by Hooker in 1827, retaining the original specific name. Sprengel referred it erroneously in 1826 to *Isochilus graminifolius* HBK., spelling the name *Isochilos*. Cogniaux (*Fl. Bras.* **3**^{6}: 493) quotes this name as *Isochilon*, a practice followed in 1923 by Kränzlin (*Pflanzenreich* **83**: 47), who apparently drew heavily on Cogniaux for both inspiration and facts. Lindley placed it in the genus *Dichaea* in 1833, retaining Swartz' specific name and thereby settling its nomenclatural troubles, so far as we can foresee at present, although Grisebach (*Fl. Brit. W. Ind.* 625) saw fit to change its name to *graminea*. Fawcett & Rendle (*Fl. Jamaica* **1**: 138. *pl. 30, f. 8–12*) gave an excellent illustration, and noted that they have 'not seen any specimens elsewhere than from Jamaica that appear to agree with the description of the species.' They also had the advantage of examining original material collected by Swartz himself.

It has nevertheless been confused by various writers with other species from widely scattered localities. Sprengel's transfer of the species in 1826 was the first of these cases, confusing it, through lack of plates or specimens, with a Colombian plant.

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[1] Contributions from the New York Botanical Garden, no. 288.

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Hooker made a similar error in 1827: after citing the Swartzian names as synonyms for *Isochilus graminoides*, he pictured a totally different plant sent him from Trinidad. Grisebach included under the species plants from as far south as Guiana. Cogniaux extended its range as far as southern Brazil, Peru, and Colombia, on the basis of various cited specimens. Kränzlin accepted all of these and pushed its limits northwest to Mexico. So far as Swartz or Fawcett and Rendle knew, and so far as our material shows, the species does not extend beyond Jamaica, and every extension of range has erroneously combined other species with it. Cogniaux illustrated an entirely different species, as a moment's comparison of his plate with that of Fawcett and Rendle will show, while Kränzlin carried the matter to the extreme by referring the Jamaica material to another species, *D. brachyphylla* Rchb. f.

There appears to be no doubt that the name *graminoides* properly belongs to the Jamaican species, of which we have abundant material agreeing in every detail with Fawcett and Rendle's illustration. I offer no opinion as to its occurrence in Cuba or other West Indian islands. Schlechter saw this condition in 1921, and gave the name *D. Cogniauxiana* to the Brazilian material described as *graminoides* by Cogniaux in the *Flora Brasiliensis*.

Specimens from British Guiana differ distinctly from *D. Cogniauxiana* in several small but important details. The petals and sepals are obtuse or subacute, shorter, broader, and never more than half as broad as long; the lip is broader than long, with shorter and broader claw, and with retrorsely curved narrow lateral lobes; the leaves shorter and somewhat narrower. It may be described as

Dichaea Rendlei n. sp. Stems several, cespitose, 10–17 cm. high; leaf-sheaths carinate, overlapping, 8 mm. long, with 6 or 7 nerves on each side; leaf-blades linear-oblong, 18–25 mm. long, 2–3 mm. wide, obtuse and minutely apiculate, entire, with 7–9 straight conspicuous nerves on each side of the median, articulate at base; peduncles solitary, filiform, surpassing the leaf-sheath by 4–5 mm.; lower bractlet obliquely ocreate, campanulate, 2.1 mm. long on the dorsal side, 1.2 mm. long below; upper bractlet linear, 1.8 mm. long; dorsal sepal ovate from a broad base, 4.2 mm. long, 2.5 mm. wide, obtuse, 3-nerved, the lateral nerves either ending free or uniting with the mid-nerve; lateral sepals ovate, 5.3 mm. long, 2.6 mm. wide, subacuminate, unsymmetrical, with 1 lateral nerve on the narrower side and 2 on the broader; lateral petals ovate, unsymmetrical, 4 mm. long, 2.1 mm. wide, obtuse or subacute, 3-nerved, the lateral nerves ending free; labellum 5 mm. long, the claw rapidly dilated, the lamina broadly anchor-shaped, subacute, 5.3 mm. wide, the lateral lobes linear, acute, 1 mm. long, retrorsely curved; ovary and fruit smooth.

Type, *La Cruz 1623*, collected between the Demerara and Berbice Rivers, lat. about 5° 50′ N., British Guiana, 15–19 July, 1922, and deposited in the herbarium of the New York Botanical Garden. Other specimens are *La Cruz 1696* and *2180*.

Dichaea trinitensis n. sp. Plants mostly solitary and simple, rarely once branched, 8–18 cm. tall, glabrous throughout; leaf-sheaths strongly conduplicate, 7 mm. long, with 3 strong nerves near each margin and several weaker intermediates; leaf-blade articulated at base, oblong, 12–17 mm. long, 3–4 mm. wide, acute, strictly entire, sometimes minutely scabrellate toward the apex, with mostly 3 nerves on each side of the median; peduncles solitary in the upper axils, filiform, nearly as long as the leaves; lower bractlet ocreiform, campanulate, apiculate and 2 mm. long above, 0.6 mm. long below; upper bractlet ovate, acuminate, 2 mm. long, 0.8 mm. wide; ovary glabrous; dorsal sepal ovate, 4.7 mm. long, 2 mm. wide, acuminate, 3-nerved, the lateral nerves confluent with the midnerve at about half its length; lateral sepals strongly saccate at base, falcately ovate, acute, 6 mm. long, 2.7 mm. wide, 3-nerved; dorsal petals ovate, slightly unsymmetrical, 4.5 mm. long, 2 mm. wide, 3-nerved, the lateral nerves extending nearly to the apex; labellum 5.3 mm. long, unguiculate below, gradually dilated above for two-thirds of its length, thence abruptly expanded into a triangular lamina 4.2 mm. wide, 7-nerved.

Type, *Broadway* without number, collected on trees, Trinidad, 3 Sept. 1919, and deposited in the herbarium of the New York Botanical Garden. Four other specimens in the same herbarium, *Britton, Coker, & Rowland 1786, Britton, Broadway, & Hazen 274, Britton, Hazen, & Mendelson 600* and *892*, from which the flowers have all fallen, agree with it in vegetative characters. The species is apparently most closely related to *Dichaea brachyphylla* Rchb. f., of southern Brazil, in which the leaves are ciliate above, the peduncles only 3 mm. long, and the sepals and petals less than 1 mm. wide. Hooker (*Exotic Flora pl. 196*) probably illustrated this plant under the name *Isochilus graminoides* in 1827, confusing it with the Jamaican *Dichaea graminoides* (Sw.) Lindl.

DICHAEA PICTA Rchb. f. Stems densely cespitose, leafy, simple or sparingly branched, 1–2 dm. long; leaf-sheaths conduplicate, 8 mm. long, with 5 principal nerves and a few intermediates on each side; leaf-blades oblong, 12–17 mm. long, 3–4 mm. wide, sharply acute, strictly entire and glabrous, usually wrinkled in drying, the obscure nerves mostly 3 on each side of the median; peduncles solitary in the axils, filiform, two-thirds as long as the subtending leaf; lower bractlet ocreiform, campanulate, acute and nearly 2 mm. long on the dorsal side, half as long below; upper bractlet linear, 2.6 mm. long, 0.4 mm. wide; dorsal sepal ovate, naviculate, 4.2 mm. long, strongly acuminate, the 3 nerves extending nearly to the apex; lateral sepals strongly saccate at base, falcate-ovate, 6.5 mm. long, 2.5 mm. wide, sharply acuminate, 4-nerved, the 3 lateral nerves abruptly inflexed at the apex and confluent with the midnerve (or the fourth with the third lateral nerve); dorsal petals ovate-oblong, 4.8 mm. long, 2 mm. wide, acuminate, slightly unsymmetrical, 5-nerved, the outer ending free, the intermediates confluent with the midnerve; labellum 5.3 mm. long, curved-ascending, the claw 2 mm. long by 1 mm. wide, gradually widened upward and thence abruptly dilated into the broadly ovate 7-nerved lamina, the lateral lobes triangular, barely retrorse.

The type material of this species was collected in Trinidad. Our Guiana specimens, *La Cruz 1504, 1930, 2602, 2814, 4264*, agree with the description in every essential feature and also match nicely with the original plate.

DICHAEA DAMMERIANA Kränzlin. The author of the species unfortunately had no flowers available for dissection. A specimen of the type number in the herbarium of the New York Botanical Garden has a single flower in good condition, and permits me to add the following to the original description (*Pflanzenreich* **83**: 41. 1923).

Outer bractlet surrounding the peduncle but not ocreiform, broadly orbicular, 2.7 mm. long, minutely apiculate; inner bractlet oblong, acute, 3 mm. long, 0.8 mm. wide; ovary densely and softly echinate; dorsal sepal oblong-obovate, broadest at two-thirds of its length, 9.5 mm. long, 3.6 mm. wide, obtuse, 5-nerved, the lateral nerves ending free, densely covered on the distal half with soft papillae; lateral sepals obovate, broadest above the middle, 8 mm. long, 4.6 mm. wide, broadly obtuse, sparsely muricate along the midvein in the distal half, 5-nerved or with a faint additional nerve, the lateral nerves ending free; dorsal petals ovate-oblong, broadest at the middle, 9 mm. long, 3.2 mm. wide, obtuse, prominently but sparsely echinate along the midvein on the basal two-thirds, with a few scattered and shorter papillae along the sides also, slightly unsymmetrical, with 1 lateral nerve on the narrower and 2 on the broader side; labellum 6.7 mm. long, strongly curved-ascending with erect sides, 7-nerved, the lateral nerves ending free with incurved tips, the claw 0.6 mm. wide at base, gradually widened for 3.5 mm. and thence abruptly dilated into a depressed-triangular, obtuse lamina 6.4 mm. wide and 2.5 mm. long.

Cymbopetalum venosum n. sp. Stem and foliage glabrous; petioles stout, narrowly two-winged, 10–15 mm. long; leaf-blades firm or subcoriaceous, elliptic-oblong, broadest at or near the middle, 15–18 cm. long, 5–6 cm. wide, abruptly subacuminate to a sharp apex, obtuse at base, with a tendency to be decurrent on the petiole, entire, slightly revolute; lateral veins arising at an angle of 80°, curved-ascending, and more or less arcuately connected near the margin, both veins and veinlets elevated on both surfaces and finely and prominently reticulate; fruits somewhat curved, brown-purple, 2–3 cm. long, 3–4-seeded, somewhat constricted between the seeds, on stipes 10–15 mm. long.

Type, *La Cruz 2004*, collected at Bartica, on the Essequibo River, British Guiana, 3–12 Sept., 1922, and deposited in the herbarium of the New York Botanical Garden. Duplicates have been distributed to the principal American herbaria.

In leaf form, *C. venosum* approaches most closely the well-known *C. brasiliense* (Vell.) Benth., in which the leaf-blades are widest distinctly above the middle, long-cuneate to the base, thin and membranous in texture, scarcely reticulate, with lateral veins strongly arcuate-connected near the margin, and on petioles only 2–3 mm. long.

Cryptocarya pachycarpa n. sp. Arborescent; bark of the twigs strongly verrucose with conspicuous lenticels; petioles stout, sharply 2-edged, verrucose, 8–12 mm. long; leaf-blades firm, dull brownish green when pressed, oblanceolate to narrowly obovate or obovate-oblong, 10–14 cm. long by 35–58 mm. wide, abruptly short-acuminate to a blunt or rounded tip, gradually cuneate to the base, glabrous; lateral veins ascending at an angle of 60°, the veinlets obscure and minutely impressed above, prominulous and finely reticulate beneath; inflorescence racemose from the upper axils, 3–6 cm. long; flowers unknown; fruiting pedicels stout, 2–5 mm. long; fruit broadly pyriform, 8–10 mm. in length and diameter, composed of a thick, corky or woody, enlarged perianth-tube crowned with the remnants of the perianth and stamens, almost completely enclosing the drupe within its distal half; drupe hemispherical, 5 mm. in diameter, smooth, tipped with a short style.

Type, *La Cruz 4215*, collected at Kamakusa, on the upper Mazaruni River, British Guiana, 11–22 July 1923, and deposited in the herbarium of the New York Botanical Garden. Duplicates have been distributed to the principal American herbaria.

While the perianth-tube surrounds the ovary in a few genera of Lauraceae, and embraces a portion of it in fruit in some of them, only the genus *Cryptocarya* ripens the perianth tube into a complete enclosure for the drupe. In all the fruiting specimens examined, the perianth-tube is completely enclosed at maturity, concealing the drupe entirely, and is comparatively thin and uniform from base to apex. In our present species the tube is greatly thickened, especially toward the base, and maintains a small orifice at the apex, through which the short style protrudes. A difference of this sort seems not only important, but even suggestive of generic rank for our plant. In the absence of flowers, it has been retained in the genus *Cryptocarya*.

The floral organs still persist on the summit of most of the fruits to some extent. It is clear from their remains, or from the scars left after their fall, that there are three sepals, three petals, and at least nine stamens. The sepals and petals are much alike in size and shape, and appear to be ovate. In one or two instances it is still evident that the anthers are 2-locellate. No trace of a fourth series of stamens or staminodes is visible.

Lecostemon sylvestre n. sp. A small tree, 5 m. high; upper portion of the stem strongly angled, slightly scabrellate, dark reddish brown; leaf-blades thin but firm, dull green, oblanceolate, the largest 32 cm. long by 8 cm. wide, broadest at two-thirds of their length, gradually rounded into an acuminate tip, gradually tapering with straight sides from above the middle to the base, entire, glabrous on both sides, minutely punctate beneath with reddish glands, the midvein prominent beneath, the lateral veins strongly ascending and outwardly arcuate; petioles prominently striate, ferruginous-scabrellate, 25–35 mm. long; racemes supra-axillary, 13 cm. long, bearing 6–8 flowers on the distal half, the rhachis flattened, prominently striate, fulvous-scabrellate; pedicels resembling the rhachis, 30 mm. long at anthesis, ascending, separated by internodes 5–15 mm. long, subtended by a triangular-subulate bract 2 mm. long, and bearing 1–3 similar bracts scattered below the flower; petals oblong-elliptic, 12 mm. long, rounded at the apex and minutely apiculate, glabrous, minutely punctate; stamens very numerous, erect, flattened, 11 mm. long, the linear marginal pollen-sacs 10 mm. long; style lateral, linear, straight, erect, 9 mm. long; hypanthium broadly obconic, 3 mm. high; sepals broadly triangular, acute, erect, 1 mm. long.

Type, *Gleason 211*, collected in dense forest between Kangaruma and Potaro Landing, British Guiana, 25–27 June 1921, and deposited in the herbarium of the New York Botanical Garden.

The genus *Lecostemon* is one of the most poorly known members of a group of genera characteristic of the forests of northern South America, of which *Hirtella*, *Licania*, and *Parinarium* are much more abundant. Displaying but little superficial resemblance to these genera, it has even been placed in the Rutaceae, although its lateral style is an indication of its affinity with the Chrysobalineae. Our species is most closely related to *L. amazonicum* Spruce, in which the leaves are coriaceous and veiny, the rhachis distinctly tomentulose, and the flowers close together, on pedicels only 5 or 6 mm. long.

Vouapa Jenmani n. sp. Arborescent; twigs glabrous, roughened with lenticels, the internodes 1–2 cm. long; leaves evenly pinnate, 5–6-jugate; petioles 10–12 mm. long, rugose, glabrous, deeply furrowed above; rhachis prominently canaliculate, its sides sometimes spreading and the rhachis then subalate; leaflets 10–17 mm. apart, subsessile, oblong-lanceolate, acute, entire, inequilateral at base, the narrow side cuneate with the swollen, petiole-like midvein exposed for 2–3 mm., the broad side obtusely cuneate to subrotund, glabrous on both sides; 3–5 prominent veins leave the midvein at the basal extension of the broad side of the leaf, other veins from the midvein, arcuately curved near the margin into two intra-marginal veins, the veinlets finely reticulate; racemes axillary, eventually 75 mm. long; flowers crowded distally, the internodes elongating after anthesis; rhachis obtusely angled, thinly but softly brown-velutinous; pedicels 3 mm. long, velutinous; bracts pubescent, 8 mm. long and ovate in bud, becoming oblong and 10 mm. long during anthesis; sepals oblong-linear, glabrous, 4 mm. long; petal 12 mm. long, its blade broadly triangular-cuneate; filaments capillary, 30 mm. long; stipe of the ovary 2 mm. long, densely pubescent, the hairs continuing as a fringe along both margins of the ovary; style filiform.

Type, *Jenman 4076*, collected on the upper Demerara River, British Guiana, Sept. 1887, and deposited in the herbarium of the New York Botanical Garden (also in the Kew Herbarium). *La Cruz 2534* agrees with it precisely in foliar characters and bears a flat, obliquely elliptic pod 13 cm. long by 7.5 cm. wide, with the dorsal margin flat, 6 mm. wide, and prominently 2-edged.

Mabea ciliata n. sp. Arborescent, 5 m. high; stem minutely puberulent or glabrous; stipules triangular-subulate, 2–3 mm. long; petioles glabrous, 7 mm. long; leaf-blades thin and membranous when young, becoming firm in age, oblong, 85–115 mm. long, 30–43 mm. wide, abruptly acuminate into an oblong, subacute cusp 6–10 mm. long, entire or obscurely undulate, broadly rounded or subcordate at base, glabrous on both surfaces, minutely purple-ciliate; lateral veins about 9 pairs, arcuately connected toward the margin, the veinlets obscure and partially reticulate; rhachis of the inflorescence purple, minutely puberulent; bracts narrowly ovate, long-acuminate, reflexed, those of the pistillate flowers glandless; glands of the staminate clusters large, pale, adnate to the rhachis by one side; pistillate flowers solitary, on minutely puberulent pedicels 5 mm. long, the sepals ovate, long-acuminate, 1.6 mm. long; staminate flowers ternate in the axils of the bracts, the pedicels purple, minutely puberulent, jointed in the middle, 6–12 mm. long, the sepals broadly ovate, subacute; stamens about 30.

Type, *Gleason 831*, collected in dense upland forest, Rockstone, British Guiana, 15 July–1 Aug. 1921, and deposited in the herbarium of the New York Botanical Garden. *Mabea ciliata* is obviously a member of the section Apodae, having glandless sepals on the pistillate flowers and axillary staminate flowers without a common peduncle. The six species of the section heretofore described have no more than 12 stamens and differ also in various other characters.

Only two works are extant which treat the Hippocrateaceae of northern South America with any degree of completeness. Miers monographed the group in 1872, basing his work chiefly if not entirely on the material available to him in England, retaining the old genus *Hippocratea*, reviving five old genera, and erecting eleven new ones, retaining 66 previously described species, of which no less than 48 necessarily received new names, and describing 50 new species. Of his sixteen genera, five belong to *Hippocratea*, in the sense of Bentham and Hooker and the Pflanzenfamilien, and eleven to *Salacia*. Six years later Peyritsch monographed the Brazilian species in the Flora Brasiliensis, including several extra-limital ones. He rejected completely Miers' classification of the family, dividing the species between the two genera *Hippocratea* and *Salacia* according to the structure of the fruit. Peyritsch apparently did not examine the herbarium material at Kew or the British Museum, since twelve species described by Miers from Brazil, with cited specimens, are neglected entirely. Since 1878, comparatively few additional species have been described from South America, notwithstanding the numerous explorations of the country, so that one may be justified in believing that the small size of the flowers on most species and the difficulty of matching flowering with fruiting material have led to most botanists neglecting the family.

Many will probably concur with Peyritsch that Miers' segregation of the family was entirely too minute. There may be some ground for separating *Kippistia* and two related groups as genera, since their styles are opposite to the stamens, rather than alternate with them, as in the rest of the family. There may also be reason for continuing the genus *Peritassa*, in which the stamens are relatively long and erect, with the connective prolonged far beyond the anther-sacs. It is also obvious that several of Miers' genera have striking habital characters, such as *Raddia*, *Tontelea*, and *Hylenaea*, but that alone is no justification for assigning them generic rank. The character of the fruit, often emphasized by Miers, is certainly more important, but fruiting material is so rare for most species that it forms by no means a satisfactory basis. On the other hand, the character of the disk, which assumes several different forms, is duplicated in *Hippocratea* and *Salacia*. Thus the disk of Miers' genus *Thermophylla*, usually merged with *Salacia*, is essentially the same as in *Hippocratea sensu angustiore*, and the low annular disk of *Prionostemma* and *Pristimera*, now considered as *Hippocratea*, is repeated in *Tontelea* and other sections of *Salacia*.

Miers' division of species is also more minute than that of Peyritsch, who found it advisable to unite no less than eight species recognized by Miers in *Hippocratea* into the single polymorphic *Hippocratea ovata* Lam. (*H. volubilis* L.), and he would probably have treated at least three others in the same fashion if they had come within the geographic range of his discussion.

Hippocratea lutea n. sp. Stems woody, apparently climbing; branches terete, glabrous, sparsely verrucose with small lenticels, the internodes 8–12 cm. long; leaves opposite; petioles glabrous, channeled above, 10–12 mm. long; blades thin but firm, yellowish green, broadly elliptic, 8–10 cm. long, 45–55 mm. wide, rounded at the apex and then prolonged into a narrowly triangular, acute, somewhat recurved cusp 10–12 mm. long by half as wide, entire, broadly obtuse or rounded at base, strictly glabrous; lateral veins usually five pairs, ascending at an angle of 50–60° and paralleling the margin nearly to the apex, veinlets conspicuously reticulate, both veins and veinlets prominently elevated and equally conspicuous on both sides; rameal leaves limited to a single pair on the larger branches, elliptic-oblong, 7–9 cm. long by 30–35 mm. wide, broadly acute at base, acuminate at apex, otherwise like the cauline; inflorescences from all the upper axils, loosely and irregularly pseudo-trichotomous, 8–10 cm. long and wide, the lowest branches 2–10 mm. from the base, the lowest internodes 2–3 cm. long, the upper gradually reduced, the lower nodes bearing one terminal and two lateral axes, the upper a terminal flower and two lateral axes, and the uppermost 3 flowers; bractlets broadly triangular-ovate, 1 mm. long, minutely denticulate; pedicels 1–3 mm. long; sepals broadly rotund, obtuse, minutely denticulate, prominently many-veined, very irregular in size, the inner nearly 2 mm. long, becoming thin and scarious toward the margin, the outer shorter and thicker; petals 5, bright yellow, broadly elliptic, 6.5 mm. long by 4.5 mm. wide, strongly boat-shaped, prominently veined, narrowly involute at the entire margin; disk thin, membranous, saucer-shaped, glabrous, 0.6 mm. high; stamens 3; filaments flat, 1.5 mm. long by 0.5 mm. wide, somewhat recurved over the margin of the disk; anthers dorsifix, 0.8 mm. long and wide, decurved, transversely ringent; ovary prominently 3-lobed; style stout, terete, 0.6 mm. long; stigmas 3, barely spreading, opposite the stamens; fruit unknown.

Type: *Jenman 2149*, collected in British Guiana, 1886, and deposited in the herbarium of the New York Botanical Garden.

Hippocratea flava n. sp. Stems woody, apparently climbing; branches glabrous, terete, with a very few lenticels, the internodes 6–8 cm. long; leaves opposite; petioles glabrous, strongly channeled above, 10–12 mm. long; blades yellow-green, very thin when young, becoming firm with age, oblong-lanceolate to oblong-elliptic, long-acuminate to a sharp apex, entire, abruptly cuneate at base, 12–17 cm. long, 45–75 mm. wide, glabrous; lateral veins 6–7 pairs, curved-ascending at an angle of about 60° and arcuately connected near the margin, veinlets conspicuously reticulate, both veins and veinlets prominently elevated on both sides; inflorescences from all the upper axils, loosely and irregularly pseudo-trichotomous or subalternately branched, the basal peduncle 3–5 cm. long, bearing a terminal flower and two lateral branches, the upper internodes progressively shorter, the uppermost bearing 3 flowers; bractlets broadly triangular, scarious, acute, 1 mm. long; lowest pedicels 20–25 mm. long, jointed 5 mm. below the flower, the upper gradually shortened to 5 mm. but always jointed 2–5 mm. below the flower; sepals broadly rotund, obtuse, essentially entire, irregular in size, the smallest 2.4 mm. long, the upper 3.5 mm. long, prominently veined and very thin and scarious at the margin; petals 5, bright yellow, broadly rotund-obovate, 7.5–8 mm. long and wide, strongly boat-shaped, prominently veined, glabrous, strictly entire; disk thin, membranous, saucer-shaped, irregularly annular, somewhat folded in 6 places, 2–2.5 mm. in diameter, 0.7 mm. high; stamens 3; filaments 1.5 mm. long, flat, much widened at base, narrowed above, arching over the margin of the disk; anthers conspicuously 2-lobed, decurved, transversely ringent, 1.0 mm. wide, 0.6 mm. long; ovary prominently 3-lobed; style stout, terete, 0.4 mm. long; stigmas 3, broadly oval, 0.5 mm. long, horizontally spreading, opposite the stamens; fruit unknown.

Type: *La Cruz 4134*, collected at Kamakusa, on the upper Mazaruni River, British Guiana, 11–22 July 1922, and deposited in the herbarium of the New York Botanical Garden. Duplicates have been distributed to the Gray Herbarium, the Philadelphia Academy of Sciences, and the National Herbarium. Other specimens are *Bond, Gillin, & Brown 59*, from the Orinoco Delta (also in the herbarium of the Philadelphia Academy of Sciences), and probably *Persaud 80*, a sterile specimen from Akyma, British Guiana (also in the herbarium of the Field Museum), referred here by leaf characters alone.

The differences between *Hippocratea lutea* and *H. flava* lie in the shape of the leaf, the character of the inflorescence, and the size of the flower. In the former the leaf is apiculate and broad, in the latter acuminate and narrow; in the former the many-flowered inflorescence branches from near the base and the flowers are on short pedicels, in the latter the basal peduncle is long, and the flowers relatively few and long-pedicelled; in *H. lutea* all parts of the flower are distinctly smaller than in *H. flava*.

Of greater importance are the similarities between the two and their common differences from other members of the family. The two agree notably in the general character of the foliage and inflorescence, in the sepals of irregular size, in the large, yellow, boat-shaped petals, in the structure of the disk and stamens, and above all in the peculiar character of stigmas opposite the stamens.

Miers was apparently the first to discover that such a character existed in the family. On that basis he separated three genera, *Kippistia*, *Cheiloclinium*, and *Anthozoma*, represented by eight species in Brazil and the Amazonian region. All of these have an unlobed ovary, and are also distinguished by various peculiarities of the disk, stamens, and stigmas, not one of which is found in our two species. Miers' genera were united with *Salacia* by Peyritsch, while our two, with their strongly 3-lobed ovaries, are almost certainly members of *Hippocratea*. Turning now to the detailed descriptions of floral structure in the segregates of that genus, as presented and illustrated by Miers, we find no mention of opposite stigmas, while his drawings and discussion lead us to believe that he would scarcely have overlooked such a structure had it been present. Four of his five segregates differ from our two species in various characters of the flower or inflorescence, but in *Pristimera* we find the same pale green, reticulately veined foliage, the same long-pedicelled flowers, the same disk and stamens, the same 3-lobed ovary, and the same prominent stigmas. In fact, the resemblance extends so far that *Jenman 2149* was identified originally as *Pristimera apiculata*. On the other hand, Miers does not mention any irregularity in the size of the sepals or the conspicuously boat-shaped petals, while emphasizing in his drawings, his description, and the derivation of his generic name the pectinate margins of both sepals and petals, while the petals of our plants are strictly entire and the sepals almost so.

Paullinia rufescens Rich. seems to be a common species in British Guiana. Its stems and foliage are regularly rufescent; the large leaflets are rounded or broadly cuneate at base, finely but not very conspicuously reticulate, with curved lateral veins, and thickly pubescent beneath. The fruit has been figured by Radlkofer both in his monograph of the genus and in the Flora Brasiliensis. Recent collections from British Guiana show that a closely related species also occurs which is as yet undescribed.

Paullinia Hitchcockii n. sp. Stem nearly terete, very finely puberulent, rufescent; leaf-rhachis angled or channeled, puberulent; leaflets 5, their blades subcoriaceous, somewhat shining above, obovate, the lower 35–50 mm. wide, 65–100 mm. long, the uppermost 55–75 mm. wide, 110–150 mm. long, all abruptly acuminate into an oblong blunt cusp nearly 1 cm. long, conspicuously sinuate-dentate along the distal half, long-cuneate (terminal leaflet) to short-cuneate or obtuse (lateral leaflets) at base, glabrous above or minutely puberulent on the midvein, sparsely pubescent beneath; lateral veins about 8 pairs, almost straight, the veinlets elevated on both sides and conspicuously reticulate; flowers lacking; spikes 5–12 cm. long, single in the axils; fruit red-brown, ellipsoid, 12 mm. long, 7 mm. in diameter, tri-alate above the middle, the surface and the wings conspicuously veiny.

Type, *Hitchcock 17,129*, collected at the Penal Settlement, British Guiana, 3–9 Dec. 1919, and deposited in the herbarium of the New York Botanical Garden. Here are referred also *La Cruz 1617*, near Wismar, *La Cruz 1725*, Dadanawa, and *La Cruz 3916*, Wanama River, Northwest District.

P. Hitchcockii may be distinguished at a glance from *P. rufescens* by its leaf characters, especially the obovate leaflets, the conspicuous terminal cusp, the prominent dentation, and the cuneate bases. The pubescence is of the same morphological character, but in *P. Hitchcockii* the hairs of the lower surface average 0.03–0.05 mm. long and stand 0.10–0.15 mm. apart, while in *P. rufescens* they are 0.05–0.10 mm. long and stand only 0.03–0.05 mm. apart. The fruit-wings of the latter species are decurrent nearly or quite to the base, while in *P. Hitchcockii* the basal portion of the fruit is quite wingless.

Paullinia arenicola n. sp. A vine 4 m. long; the finely striate stem minutely puberulent; leaf-rhachis prominently angled or channeled, minutely puberulent; leaflets 5, subcoriaceous, dull green or somewhat shining, narrowly oblong-elliptic or oblong-lanceolate, 8–10 cm. long, 30–38 mm. wide, broadest at or below the middle and gradually tapering to a blunt apex, conspicuously dentate throughout with blunt, salient, somewhat callous teeth mostly 8–15 mm. apart and 2–3 mm. long, cuneate to obtuse at base, glabrous on both surfaces; lateral veins about 8 pairs, ascending at an angle of 45°, the veinlets prominently elevated and conspicuously reticulate on both sides; spikes solitary, axillary, 5–10 cm. long, closely puberulent; stipe of the fruit 5 mm. long; fruit-body ellipsoid, 12 mm. long, 7 mm. in diameter, tri-alate above the middle, the wings decurrent to the base, body and wings red-brown, prominently veined.

Type, *Gleason 803*, collected on dry sand hills, east of Rockstone, British Guiana, 22–30 July 1921, and deposited in the herbarium of the New York Botanical Garden. A second collection is *Gleason 818*, from the same locality. The measurements are taken from the type; in the second collection the leaves are smaller and somewhat shining on the upper surface. *P. arenicola* is also related to *P. rufescens*, and differs in its small, glabrous, strongly dentate, and conspicuously reticulate leaves.

Cupania obovata n. sp. Leaf-rhachis closely and finely ferruginous-puberulent, terete below, flattened and strongly angled above; leaflets about 7, thin and membranous, obovate-oblong, broadly rounded or somewhat retuse at the apex, entire or slightly undulate, cuneate to a petiolule about 5 mm. long, minutely puberulent along the midvein on both sides, otherwise glabrous, the lower 30–38 by 50–65 mm., the uppermost 45 by 110 mm.; lateral veins 6–8 pairs, curved-ascending, impressed above with obscure veinlets, the venation elevated and conspicuously reticulate beneath; panicles freely branched, 20–30 cm. long, the branches prominently channeled, minutely puberulent below, becoming tomentulose above; pedicels 1 mm. long; sepals broadly obovate-oblong, 1.7 mm. long, 1–1.3 mm. wide, closely tomentose; petals 5, apparently white, broadly obovate, 1.3 mm. long, 1 mm. wide, thinly white-villous, especially on the basal half; scales 2, semi-obovate, 0.8 mm. long, attached to the side and base of the petal, densely white villous with hairs 0.6 mm. long; stamens 8, intradiscal, about equal; filaments erect, stout, 0.9 mm. long, densely villous on the basal two-thirds; ovary about equaling the filaments; disk fleshy, annular, continuous.

Type, *La Cruz 4379*, collected at Kamakusa, on the upper Mazaruni River, British Guiana, 11–22 July 1923, and deposited in the herbarium of the New York Botanical Garden. The obovate rounded leaflets give the plant the aspect of a *Matayba;* although fruit is unfortunately lacking, the character of the scales on the petals indicates that it is a *Cupania*.

Lysiostyles pubescens n. sp. Climbing woody vine, the young twigs closely and finely pubescent with reddish hairs, the older stems glabrous and exfoliating thin layers of bark; petioles 10–15 mm. long, pubescent like the stem; leaf-blades firm or subcoriaceous, elliptic-oblong, 10–14 cm. long, 5–8 cm. wide, rounded toward the apex into a very short, triangular, obtuse point, entire, rounded or subcordate at base, glabrous above, closely subtomentose beneath with brown hairs; veins obscure above, elevated and prominently reticulate beneath; inflorescences numerous, axillary, 3–8 cm. long, pubescent like the stem, consisting of a rhachis bearing 5–10, 3–5-flowered cymes on peduncles 2–3 mm. long; bractlets minute; pedicels 1–2 mm. long; calyx densely pubescent, 2 mm. long, two outer lobes broadly ovate, subacute, three inner lobes depressed rotund, broader than wide, obtuse; corolla-tube glabrous, 1.5 mm. long; corolla-lobes somewhat spreading, triangular-lanceolate, 3 mm. long, acute, densely brown-pubescent without, terminated by a filiform appendage 1.5–2 mm. long; filaments glabrous, 1 mm. long, slightly tapering upwards; anthers 0.8 mm. long, the anther-sacs about two-thirds as long as the stout connective; ovary spherical, densely hirsute with erect hairs; styles separate to the base, glabrous, 0.8 mm. long; stigmas capitate, spherical, 0.2 mm. in diameter.

Type, *Persaud 67*, collected at Wismar, British Guiana, July 1924, and deposited in the herbarium of the New York Botanical Garden. *Lysiostyles pubescens* differs from *L. scandens* Benth., the only species of the genus hitherto known, chiefly in the shape of the leaf at base and apex, in the glabrous upper leaf surface, in the acute outer sepals, and in the completely hirsute ovary.

TRICHANTHERA GIGANTEA (H. & B.) Nees. This acanthaceous tree, originally described from Colombia, seems to have a wide distribution across northern South America. It has been recently collected in the department of Bolivar by Pennell, *4101;* in El Valle by Pennell and Killip, *6193;* in Portuguesa, Venezuela, by Pittier, *12,056*, and in the Northwest District of British Guiana by La Cruz, *1348*. A still older specimen in the Kew herbarium, *Jenman 371*, extends the range to the eastern boundary of British Guiana. These lowland forms have larger flowers, more hirsute filaments, smaller and more loosely branched inflorescences, and somewhat glaucous leaves, with the veins not elevated on the upper side, and may be distinguished as the variety **guianensis.**

Miconia Toroi n. sp. Section Amblyarrhena: Stems strongly obtusely 4-angled, the internodes 2–4 cm. long, glabrous, the nodes densely hirsute with brownish hairs 3–5 mm. long; petioles 8–15 mm. long, densely hirsute like the nodes; leaf-blades membranous, dull green, oblong-elliptic, as much as 175 mm. long by 75 mm. broad, sharply acuminate, minutely dentate and ciliate, cuneate at base, 3-nerved with a faint additional marginal pair, the secondaries strongly ascending and somewhat reversely arcuate; upper surface thinly hirsute with straight brown hairs 1–1.8 mm. long; lower surface similarly hirsute along the secondaries and veinlets and densely hirsute with hairs 1–2 mm. long on the primaries; inflorescence 13 cm. long, the sessile 5-merous flowers glomerate or subsecund at the end of short lateral branches, the axes and branches finely pubescent in two opposite lines; bractlets minute, obovate, conspicuously ciliate; hypanthium urceolate, glabrous, 1.8 mm. long to the torus; calyx strongly thickened distally into a fleshy ring, with 5 spreading or somewhat reflexed exterior teeth and 5 broadly triangular sepals each 0.1 mm. long; petals obovate-oblong, retuse, glabrous, 2.8 mm. long, 1.6 mm. wide, pinkish; stamens isomorphic, all turned in the same direction at anthesis; filaments slender, 1.7–1.8 mm. long; anthers stout, bright purple, slightly retuse, 1.25 or 1.5 mm. long, opening by a minute terminal pore, the connective neither appendaged nor prolonged; ovary about one-third free, its glabrous summit strongly ribbed; style straight, terete, 2.2 mm. long, slightly tapering distally; stigma capitate.

Type, *Toro 278*, collected at Angelopolis, near Medellín, Colombia, 27 July 1927, and deposited in the herbarium of the New York Botanical Garden. The relation of *M. Toroi* to the group including the familiar *M. ciliata* and *M. racemosa* is immediately obvious. It most nearly resembles *M. pulvinata* Gleason, from which it is distinguished by the fleshier calyx, the densely hirsute nodes, the longer and more hirsute petioles, and the pubescent leaves.

Blepharodon ornatum n. sp. Stems twining, slender, glabrous, with a ring of subulate reflexed appendages 1 mm. long at the nodes; petioles slender, glabrous, 3–6 mm. long; leaf-blades firm, elliptic or oblong, 30–45 mm. long, 12–18 mm. wide, acute or subacuminate and aristate at apex, entire, cuneate to an acute base, glabrous, the upper surface almost veinless, the lower paler green and obscurely veined; leaf-base with 2 or 3 subulate reflexed appendages 1–2 mm. long; peduncles slender, glabrous, about 1 cm. long, with a whorl of subulate bracts about 1 mm. long above the middle and another at the summit; pedicels about 3, umbellate, 15–25 mm. long; sepals spreading or reflexed, ovate, 2.5 mm. long, the center finely reticulate, the margins scarious; corolla rotate; petals ovate-triangular, 8 mm. long, connate for one-third of their length, reticulately veined, pubescent on the upper side near the margin; lobes of the corona 4 mm. long, adnate to the stamens for half their length, the basal portion laterally compressed and somewhat ventricose, outer lobe flaring, ovate, obtuse, inner lobe erect, acuminate; stamens tipped with a semi-circular hyaline appendage arching over the 5-tuberculate stigma.

Type, *Gleason 805*, collected on dry sandhills, east of Rockstone, British Guiana, July 1921, and deposited in the herbarium of the New York Botanical Garden. It is distinguished from *B. Steudelianum* (Miq.) Pulle by the shape of the corona, the longer, bracted peduncles, the few-flowered inflorescence, and the subulate appendages at the nodes and the base of the leaves.

Extraordinary sexual phenomena in plants[1]

JOHN H. SCHAFFNER

The usual phenomena of sexuality may be classified under a few definite terms as: primary and secondary sexual states and characters; specific attraction and fusion of gametes (fertilization); specific attraction, pairing, and segregation of diploid chromosome complements (reduction division); diploid and haploid conditions; the influence of secondary sexual states in producing sexual dimorphisms; the time of sex-determination and sex-reversal; and the distribution of sexual states in the individual as represented by unisexual and hermaphroditic individuals and monosporangiate (diecious) and bisporangiate individuals of various types and degrees. All of these conditions are involved in the usual expressions of sexuality in the course of the ontogenetic and phylogenetic developments. There are also various abnormal peculiarities which are widespread in both the plant and animal kingdoms which must have a prominent place in any comprehensive study of sexuality; among which may be mentioned: self and cross sterility; specific compatibilities and incompatibilities; and the several types of parthenogenetic developments in which cells, after male or female sexualization, return either to a secondary sexual state or to a neutral vegetative condition, new individuals being produced without a union with a cell of the opposite sexual state.

In the plant kingdom a number of extraordinary conditions have evolved which tend to throw considerable light on the problem of the nature of sex, and it is the purpose of this paper to catalog some of the more common and well-known cases, in order that they may be brought into the general discussion of the subject which at present has such a prominent place in biological thought.

When we think of sexuality as + (female) and − (male) conditions we are apt to attribute definite differential qualities to the two conditions, and such may really exist, but, on the other hand, the differences may be only due to degrees of intensity of development of a common condition. In *Spirogyra* and other conjugates, as shown by various investigators, three types of special reproductive cells may be produced—aplanospores, zygospores, and parthenospores. Both the plus and minus cells may produce parthenospores. In organisms with more highly differentiated gametes the female cell alone retains the capacity for parthenogenetic development. This is probably because of its much lower metabolism as indicated by its lower catalase activity, its food-storing ability, etc. In the higher Spirogyras, the entire filament is normally determined as male or female at the time of conjugation, but as various workers have shown, and as is easily observed in certain species, the cells of a filament may react as + (female) toward one filament and as − (male) toward another. This becomes apparent when a filament is parallel with another filament for only a part of its length and comes to be parallel with a third filament for the remaining part. This suggests that possibly in some stages of development, at least, male and female are but relative terms and + and − only different levels or degrees of the same fundamental condition. Various cases have also been reported where each of two conjugating filaments reacts in one part as female and in another as male toward the other. All such phenomena are decidedly illuminating when it is remembered that these filaments are haploids and have originated from a reduction spore.

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The Oedogoniaceae present several remarkable conditions in the evolution of their sexuality. Only one phase of the subject will be considered here. In both *Oedogonium* and *Bulbochaete*, certain species produce so-called dwarf males. Among the species which produce filaments with oospheres and androspores, and dwarf males from the androspores, may be mentioned *Oe. Borisianum* (Le Cl.) Wittr., *Oe. nebraskense* Ohashi, and *Oe. Wolleanum* Wittr. The haploid individual coming from the reduction spore, instead of producing oospheres and spermatozoids, like a normal hermaphroditic *Oedogonium*, produces, as stated above, oospheres and androspores. The androspores must be regarded as derived phylogenetically from original spermatozoids. The egg cell or oosphere is usually situated above a sister cell which is usually called a suffultory cell. This cell apparently has some female qualities. The androspores show a partial primary sexual state and are attracted to the oogonium or to the suffultory cell. In the species mentioned they usually settle down on the suffultory cell. In some species of *Oedogonium* and *Bulbochaete* they mostly settle upon the oogonium itself. Thus these androspores plainly show a partial primary sexual state. They react toward and are attracted by the suffultory cell or the oogonium, but at this point the ordinary primary properties disappear or cease to act, and through parthenogenetic development a dwarf male filament is produced as an epiphyte, which finally furnishes the functional spermatozoids and these not only have attractive properties but also the power of fusing with the female gamete. The dwarf male, of course, shows decided secondary sexual dimorphism, not only because its cells are in the secondary male state, but also because it originated parthenogenetically from a cell which had developed at least a partial primary male state, which has a decided effect on its functional activity at the very beginning. The Oedogoniaceae are probably the highest plants in which parthenogenetic male development is possible. In plants higher in the scale, the spermatozoid is apparently too extremely differentiated morphologically and physiologically to be able to germinate; so parthenogensis is known only in the female gamete.

In the Oedogoniaceae then, we have a series of unusual sexual phenomena, all coming from a single haploid spore, the whole series of sexual changes and peculiarities, both normal and abnormal, being produced without a change of chromosome complement. Recently Goldschmidt and others have attempted to develop a theory of sexuality based on the idea of a balance of genes. Anyone can see that a 'balance of genes' is not involved in the matter, since the same genes and the same chromosome complement is maintained from beginning to end. The original haploid filament exhibits a neutral state, secondary female and primary female states, partial primary male state and perhaps a partial primary female state in the suffultory cell, while the dwarf male with the same hereditary complex, with the original complement of chromosomes, shows only a secondary male state and a primary male state. The same 'balance of genes' has produced practically every kind of sex reaction known. The change from one reaction to another is not caused by a change in the balance of genes. It will also be noted that when the cells are in a neutral vegetative state a very different filament is produced from that produced when the cells are in the secondary male state. If a filament could be developed with the secondary female state it would probably show a trimorphism with the other two.

The higher fungi, including both ascomycetous and basidiomycetous groups, have developed a very unusual and remarkable sexual condition. These plants must be regarded as having evolved from the condition of a simple haploid sexual cycle. In this condition the gametes fuse to form the zygote and at the germination of the zygote reduction takes place, giving rise to haploid spores from which the haploid individual is developed, as in the Conjugatae, the simpler *Oedogonia*, and most of the other green algae. In these higher fungi a haploid mycelium is the normal initial stage with uninucleate cells. When sexual reproduction begins, two cells become sexualized as + and − and conjugate directly, as shown by various investigators, a pore being developed between the fused cell walls and the minus determined protoplast passes over into the plus determined cell. However, no fusion of the nuclei takes place. The pair of haploid nuclei must, however, retain some degree of a primary sexual state, since they can so influence each other that they normally divide simultaneously and each new cell apparently receives a pair of daughter nuclei. Thus a mycelium is developed with binucleate cells. In the Ascomycetae this conjugate phase is usually not extensive, but in the Basidiomycetae and Teliosporae an extensive binucleate mycelium may be developed. In the rusts, as in *Puccinia graminis* Pers., the binucleate phase at first produces aeciospores, which may be regarded as simply a special kind of conidia. These aeciospores each have a pair of nuclei and propagate the rust on the wheat plant, developing a conjugate phase or generation. In all Ascomycetae, Teliosporae, and Basidiomycetae, apparently, a cell is finally produced—the initial ascus cell, teliospore, or basidium—in which the pair of nuclei develop the complete primary sexual states and immediately fuse, giving rise to a normal diploid zygote. This zygote nucleus, on dividing, undergoes the reduction division, as is usual in plants with a simple, haploid, sexual cycle, and the resulting ascospores or basidiospores are haploid again with a single nucleus.

In the Basidiomycetae, the binucleate phase has certain interesting complications, in the development of clamp connections, which seem to have some relation to a + and − condition of the conjugate nuclei.

In this case, the sexualization of the cells, which should end in perfect gametes with primary sexual states, apparently stops short of the complete process, and only partial primary sexual states are developed. The sexualization, however, goes one step further than is the case in the androspores of *Oedogonoium* and *Bulbochaete*, so that there is not only an attractive property and reaction toward the opposite sexual state, but an actual penetration of the one protoplast into the other. The ability to fuse is either absent or is neutralized in the presence of the opposite sexual state.

In certain Basidiomycetae various workers have apparently found a number of compatible and incompatible strains within the species, which seem to be involved in the sexual interactions of certain heterothallic mycelia. If there are numerous strains in some of these species of Agarics, as we know them in various species of rusts and smuts, it may be possible that a careful study of them would throw some light on the relation of hereditary strains to sexual compatibility and incompatibility. The whole group needs careful study in this respect, not only of the phenomena themselves, but especially from the standpoint of correct interpretation, which at present seems to be following the fantastic lines developed in connection with sexual phenomena in the higher plants and animals. Apparently sex-reversal is an easily induced process in many of the heterothallic species, since under artificial culture the heterothallic or unisexual mycelia pass over spontaneously to the homothallic or hermaphroditic condition after a time, as found by several investigators, more especially by Vandendries in *Coprinus radians* (Desm.) Fr., and by Miss Newton in *Coprinus Rostrupianus* Hansen.

The conjugate condition is then to be regarded as an intercalated phase, brought about, in the phylogeny of the group, by a mutative change which interfered with the complete primary sexualization, for the time being, of the gametes. But by a parthenogenetic vegetative growth a binucleate phase or generation was produced which shows a succession of evolutionary advances in the various ascomycetous and basidiomycetous groups. With the complete primary sexualization of the paired nuclei the conjugate phase disappears in the formation of the diploid cell or zygote.

Thus we must recognize three general types of sexual states—the secondary sexual state, the partial primary sexual state, and the complete primary sexual state. The partial primary sexual state shows two recognizable phases or conditions; first, primary sexualization to the extent that only attraction toward the opposite state is shown but no fusion whatever, as in the androspores of *Oedogonium* and *Bulbachaete;* second, primary sexualization to the extent that not only attractive properties are present to such a degree that cytoplasmic fusion is accomplished, but also association of the + and − nuclei, without nuclear fusion, however. Such partial sexual states may perhaps also arise in the sexualization of the synaptic chromosomes and become a prolific source of chromosome disturbances and hereditary irregularities.

When a cell is in the secondary sexual state, its hereditary expression and activity are influenced so that sexual dimorphisms are produced. When a cell is in the partial primary sexual state, attractive properties of various degrees are developed, but these do not lead to the fusion of the sexual nuclei, and in the lowest condition not even to cytoplasmic fusion. When a cell is in the complete primary sexual state, there is not only attraction and reaction toward the opposite sexual state, but, if nothing interferes, complete fusion of the two nuclei is accomplished. The fusion of the nuclei brings about a neutral condition, or a secondary male or female state may follow. In some cases in the higher plants at least, as will be shown below, fusion of nuclei may be followed by a further primary sexualization immediately. In all homosporous plants and in all heterosporous species except the diecious ones, fusion of the gametes ends definitely in a neutral vegetative state, the so-called nonsexual sporophyte. The three types or phases of sexualization are developed both as male or as female conditions and have no direct bearing on the differential involved in comparing these conditions with each other as + and − manifestations of unknown physical phenomena.

Sex reversal has been found to be rather common in the unisexual gametophytes of certain homosporous plants and also in the monecious and diecious species of the heterosporous groups. But the sexual condition and differentiation of the gametophytes of heterosporous plants seems to be very extremely fixed. The sexual state handed over to them from the sporophyte seems to become so extreme and the sexual dimorphism so great that we ordinarily think no sex reversal in such an individual could be possible, and this is probably true so far as the male gametophyte is concerned. But there are certain cases in the gymnosperms, and a very general phenomenon in the angiosperms, which clearly show that cells from the female gametophyte may develop + and − relations and react toward each other as female and male, in other words develop complete primary female and male states, which condition brings about fusion of the two types of nuclei.

In the gymnosperms, the archegonium develops an egg and a ventral canal cell. The nuclei are sisters. Usually the ventral canal cell disorganizes promptly. There are sporadic cases, however, in which the ventral canal nucleus does not degenerate but fuses with the egg nucleus. Such fusions have been observed in several genera, especially in *Pinus* and *Picea*. The ventral canal cell in its degenerative process must arrive at a neutral condition and if the degenerative process is arrested it may pass over to the − or male state and fusion with the + egg nucleus is the inevitable result. Here then we have a case in which a cell of a highly differentiated female gametophyte, a sister cell of the egg itself, has its sexual state reversed to a primary male state. It must not be forgotten that these cells come from a haploid individual, so that there has been no reduction of chromosomes and no shifting of hereditary potentialities. The change from reproductive female cell to the male condition, is, of course, well known in animals, as in chickens and pigeons. In the animal, however, the change takes place in a diploid individual.

The angiosperms have what may be regarded as the most remarkable phenomena in the plant kingdom in the processes of triple and multiple fusions. There is apparently nothing corresponding to these conditions in any other plant or animal group.

In certain gymnosperms, as reported by Miss Herzfeld for *Ephedra campylopoda* Meyer, one of the two male nuclei fuses with the ventral canal nucleus while the other fuses with the egg nucleus. This simply indicates that in the given case the sister nuclei had both passed from the secondary female state to the primary female state, which condition should be expected occasionally, since the joint-firs represent a group with a much shortened gametophytic ontogeny, and during the phylogenetic history the differentiation process, through which primary sexualization is brought about, has been thrown back continuously into an earlier stage because of an abbreviation of the cell lineage. In so far as these abnormalities involve the primary sexualization of normally secondary sexual cells, they correspond to the condition of triple fusion in the embryo-sac of the angiosperms.

In the usual type of triple fusion, as developed in the Anthophyta, the two so-called polar nuclei of the female gametophyte fuse with each other and with the second sperm from the pollen tube about the same time that fertilization is accomplished through the fusion of the egg nucleus and the first sperm. It must be remembered that the upper polar nucleus is a sister nucleus of the egg nucleus and the lower polar nucleus is a sister of the upper of the three antipodals which according to Porsch's view probably also represents a degenerate egg phylogenetically. Every possible order in the fusion of the three nuclei has been observed, so that the triple fusion is brought about in a variety of ways. Often the polar nuclei have already fused when the pollen-tube enters the embryo-sac and the sperm nucleus unites with the fusion nucleus. This condition has been reported for various Ranunculaceae, *Tricyrtis*, *Datura*, *Silphium*, etc. In other cases the polar nuclei and the second sperm may all be attracted and all fuse together at the same time. In some cases the male nucleus may come in contact with either of the polar nuclei while they are still separate; in some cases the male nucleus fuses with the upper polar first and the lower is then attracted to and fuses with this diploid nucleus; in still other cases the sperm is attracted to the lower polar first. These differences in the order of fusions are explainable on the hypothesis that the polar nuclei are not always sexualized at the same time, so that either the upper or the lower nucleus may attain primary sexual maturity before the other. In either case the polar nucleus will have a + reaction toward the extremely male sperm nucleus. Now all the cells of the embryo sac are originally in the secondary female state which was handed over from the megaspore and thus always show an enormous secondary sexual dimorphism when compared with those of the male gametophyte. But in case the two polars fuse together first, they have the + and − reaction toward each other. In probably most cases the lower one has developed the minus or male reaction. In *Alisma* and *Sagittaria*, which the writer studied intensively, the lower polar nucleus was always the smaller. In *Sagittaria latifolia* Willd. the upper polar nucleus is by far the largest nucleus in the embryo sac, considerably larger than even the nucleus of the egg. Thus it is evident that the difference in size of the two polars is not entirely due to their positions in the upper and lower ends of the sac but, to a certain extent at least, to some differential condition or state which is influencing their development. This difference in sexual development or reaction of two cells of the female gametophyte may be comparable to the opposite, reactions which take place in a sexually differentiated *Spirogyra* filament, as presented above, where part of the filament may react as + toward one filament and the other part as − toward another filament. We can then properly speak of a reversal in the one or the other polar nucleus from the female state to the male state.

There has been much speculation as to whether this triple fusion should be regarded as a fertilization, since no sporophyte embryo results from it, but a xeniophyte. There is no essential difference in the attraction and fusion of the nuclei in this case from a normal fertilization. There is a mixture of chromosomes which subsequently act as a unity in the formation of nuclei by indirect nuclear division. That an entirely different course of differentiation takes place is due to neither the heredity involved nor to the number of chromosomes. We know that a sporophyte may result from a haploid or triploid nucleus as well as from a diploid one. The difference in the subsequent hereditary expression is due to the positions and functional states of the cells involved.

Now if triple fusion were the only unusual sexual event in the Anthophyta, we might rest content with our simpler ideas of what is involved in the sexualization of a cell. The most remarkable conditions, however, are the multiple fusions of cells of the embryo sacs of such genera as *Peperomia*, *Gunnera*, etc. In *Peperomia* by an added cell division stage, a 16-celled female gametophyte is produced. These 16-celled sacs must be regarded as secondary conditions derived from a normal eight-celled sac, as Johnson has maintained, and the multiple fusions occurring in them as secondary developments from an original triple fusion. Probably the most extreme case is that which Johnson found in *Peperomia hispidula* Dietr. where 14 of the nuclei of the 16-celled embryo sac fuse together to produce the primary endosperm nucleus. There was no evidence of a fusion with the second sperm from the pollen tube. In *Peperomia pellucida* Kunth eight nuclei fuse to form the definitive nucleus. These remarkable nuclear fusions involve primary sexualization with the + and − interactions although other properties may be involved. In various plants, like *Fucus*, the egg attracts many sperms, but the fusion is nevertheless with a single one.

Among the lower plants, there are several classes which show mutual attractions between cells which do not appear to involve the ordinary + and − reactions of sexualized cells. The attraction of the cells to form a plasmodium in the Myxomycetae, the gregarious association of the cells in the pseudoplasmodium of the Myxobacteriales, and the symmetrical associations of cells resulting in the colonies of *Pediastrum* and *Hydrodictyon* are probably due to special physical states or conditions not directly related to sexualization, or if sexualization is involved we must assume for the time being that other, quite distinct states and properties are present at the same time. With our present imperfect knowledge of the nature of such states and properties it will be most expedient to regard such associations as appear in *Hydrodictyon*, etc. as of a different physical order from primary sexual states, although it must be admitted that there are some similarities in the reactions. In the multiple fusions of nuclei in the abnormal embryo sacs additional states and properties may also be developed, as intimated above, beside the usual + and − or male and female primary sexualization. The wonder is that a workable and working nucleus comes out, and it is not surprising that in *Peperomia hispidula* Dietr. the primary endosperm nucleus gives rise to only about 40 endosperm cells.

Whatever hypotheses or explanations of the sexual states and conditions may be attempted, the remarkable sexual phenomena recounted above must be taken into account as well as the conditions which we assume to be normal, otherwise they will be of little or no value in the scientific attempt to solve the mysteries of sexuality. It seems foolish to the writer to attempt theories until we have at least made a study of the phenomena that may possibly have a fundamental bearing on the problem we are attempting to solve. It must also be evident to any one acquainted with even only the ordinary phenomena of sexuality, that the recent genetic speculations which have been put forth with such seemingly great confidence have very little to do with the matter, and their main effect seems to be to teach young biologists certain dogmas that make even the simplest and easiest experimentation on sex control and sex reversal seem impossible.

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INDEX TO AMERICAN BOTANICAL LITERATURE
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Adams, J. A short guide to Canadian genera of seed plants. Canada Dept. Agr. Bull. n. s. 78: 1–97. 1927.

Asami, Y. On the self-sterility of the Japanese pear. Proc. Am. Soc. Hort. Sci. **23**: 122–127. "1926" 1927.

Baldwin, I. L., Fred, E. B., & Hastings, E. G. Grouping of legumes according to biological reactions of their seed proteins. Bot. Gaz. **83**: 217–243. *f. 1, 2.* 25 My 1927.

Barrel, G. H. Walnut in Amazonas. Tropical Woods 10: 51–53. 1 Je 1927.

Bartlett, H. H. Sumatran plants collected in Asahan and Karoland with notes on their vernacular names. Papers Michigan Acad. Sci. **6**: 1–66. Mr 1927.

Baxter, D. V. Some Porias from the region of the Lake states. Papers Michigan Acad. Sci. **6**: 67–76. *pl. 1–6.* Mr 1927.

Beals, A. T. Dr. George N. Best, 1846–1926. Bryologist **30**: 20–22. *port.* "Mr" 15 Jl 1927.

Beckett, R. E. Growth of fruiting parts in *Gossypium cernuum*, an Asiatic cotton. Jour. Agr. Res. **35**: 97–106. *f. 1–4.* 15 Jl 1927.

Belling, J. The attachments of chromosomes at the reduction division in flowering plants. Jour. Genetics **18**: 177–204. *f. 1–16.* Je 1927.

Belling, J. Configurations of bivalents of *Hyacinthus* with regard to segmental interchange. Biol. Bull. **52**: 480–487. *f. 1–5.* Je 1927.

Belling, J. The nomenclature of chromosome groups. Nature **119**: 926. 25 Je 1927.

Bennett, C. W. Virus diseases of raspberries. Michigan Agr. Exp. Sta. Tech. Bull. 80: 1–38. *pl. 1–9.* My 1927.

Benoist, R. Sur le bois de quelques Anonacées americaines. Bull. Soc. Bot. France **74**: 281–285. Mr–Ap 1927.

Berg, A. Tomato late blight and its relation to late blight of potato. West Virginia Agr. Exp. Sta. Bull. 205: 1–31. *f. 1–7.* Jl 1926.

Blanchard, F. C. Heterogametic and homogametic hybrids between two mutations of *Oenothera pratincola.* Papers Michigan Acad. Sci. **6**: 133–180. Mr 1927.

Blanchard, F. C., & Bartlett, H. H. The inheritance of red bud color in crosses of *Oenothera pratincola* and related forms. Papers Michigan Acad. Sci. **6**: 77–132. Mr 1927.

Blinks, L. R. On *Valonia* and *Halicystis* in eastern America. Science II. **65**: 429–430. 29 Ap 1927.

Bowman, H. H. M., & Yee, M. A. The nutritive value of the mung bean. Papers Michigan Acad. Sci. **6**: 181–188. *pl. 7.* Mr 1927.

Phaseolus aureus.

Boynton, K. R. Tulips. Jour. N. Y. Bot. Gard. **28**: 143–148. *f. 6.* Je 1927.

Abstract of a lecture.

Brink, R. A. Genetics and the problems of development. Am. Nat. **61**: 280–283. My–Je 1927.

Brink, R. A. Studies on pollen tube development in a partially sterile hybrid between *Linaria vulgaris* and *L. purpurea.* Zeitsch. Induk. Abstamm. Vererb. **44**: 129–148. *f. 1.* 1927.

Britton, N. L. Further botanical studies in Porto Rico. Jour. N. Y. Bot. Gard. **28**: 125–131. *f. 1, 2.* Je 1927.

Bush, B. F. The glabrate species of *Tilia.* Bull. Torrey Club **54**: 231–248. "Mr" 2 My 1927.

Bush, B. F. Some species of *Viburnum*. Am. Midl. Nat. **10:** 225–243. Mr–My 1927.

Caldis, P. C. Etiology and transmission of endosepsis (internal rot) of the fruit of the fig. Hilgardia **2:** 287–328. *pl. 1–16.* Ja 1927.

Caldis, P. C., & Coons, G. H. Achromatic variations in pathogenic fungi. Papers Michigan Acad. Sci. **6:** 189–236. *pl. 8–18.* Mr 1927.

Canby, M. L. The genus *Corethrogyne* in southern California. Bull. So. California Acad. Sci. **26:** 8–16. Ja–Ap 1927.

Carter, W. A technic for use with homopterous vectors of plant disease, with special reference to the sugar-beet leaf hopper, *Eutettix tenellus* Baker. Jour. Agr. Res. **34:** 449–451. *f. 1.* 1 Mr 1927.

Chang, C. Y. Origin and development of tissues in rhizome of *Pteris aquilina*. Bot. Gaz. **83:** 288–306. *f. 1–18.* 25 My 1927.

Coker, W. C. New or noteworthy Basidiomycetes. Jour. Elisha Mitchell Sci. Soc. **42:** 251–257. *pl. 47–49.* My 1927.

In *Clavaria*, *Lachnocladium*, *Geaster*, and *Arachnion*.

Coker, W. C. Other water molds from the soil. Jour. Elisha Mitchell Sci. Soc. **42:** 207. *pl. 27–36.* My 1927.

Genus *Calyptralegnia*, and several species described as new.

Coker, W. C., & Patterson, P. M. A new species of *Pythium*. Jour. Elisha Mitchell Sci. Soc. **42:** 247–250. *pl. 46.* My 1927.

P. torulosum.

Colby, A. S. Notes on self-fertility of some gooseberry varieties. Proc. Am. Soc. Hort. Sci. **23:** 138–140. "1926" 1927.

Colley, R. H., Hartley, C., & Taylor, M. W. A morphologic and biometric comparison of *Cronartium ribicola* and *Cronartium occidentale* in the aecial stage. Jour. Agr. Res. **34:** 511–532. *f. 1–5.* 15 Mr 1927.

Collins, G. N. Yield and the number of seminal roots in maize. Jour. Am. Soc. Agron. **19**: 466–467. My 1927.

Conner, A. B., & Karper, R. E. Hybrid vigor in sorghum. Texas Agr. Exp. Sta. Bull. 359: 1–23. *f. 1–6.* My 1927.

Cook, O. F. Barley in Egypt before wheat. Jour. Hered. **18**: 175–176. "Ap" 7 Je 1927.

Cook, O. F. New genera and species of ivory palms from Colombia, Ecuador and Peru. Jour. Washington Acad. Sci. **17**: 218–230. 4 My 1927.

In *Phytelephas* and *Ammandra.*

Coons, G. H., & Stewart, D. Prevention of seedling diseases of sugar beets. Phytopathology **17**: 259–296. *f. 1–9.* 15 My 1927.

Cooper, N. David Douglas. Gard. Chron. III. **80**: 250–251. 25 S 1926.

Couch, J. N. Some new water fungi from the soil, with observations on spore formation. Jour. Elisha Mitchell. Sci. Soc. **42**: 227–242. *pl. 37–43.* My 1927.

Coulter, J. M. Revision of the genus *Myrrhidendron.* Jour. Washington Acad. Sci. **17**: 213–215. 4 My 1927.

2 species described as new.

Crandall, C. S. Apple breeding at the University of Illinois. Illinois Agr. Exp. Sta. Bull. 275: 341–599. *f. 1–113.* Je 1926.

Culpepper, C. W., & Magoon, C. A. A study of the factors determining quality in sweet corn. Jour. Agr. Res. **34**: 413–434. *f. 1–6.* 1 Mr 1927.

Darrow, G. M. Sterility and fertility in the strawberry. Jour. Agr. Res. **34**: 393–411. *f. 1–14.* 1 Mr 1927.

Davidson, A. Botanical field notes. Bull. So. California Acad. Sci. **26**: 16. Ja–Ap 1927.

Detjen, L. R. A preliminary report on cabbage breeding. Proc. Am. Soc. Hort. Sci. **23**: 325–332. "1926" 1927.

Dickey, S. S. Cow-poison. Nat. Mag. **9**: 384. *illust.* Je 1927.
Veratrum viride.

Dobbie, H. B. Finding a new fern. Am. Fern. Jour. **17**: 64–66. 18 Je 1927.
Lomaria capensis.

Doby, G., & Hibbard, R. P. Nutrient ions of plants and the ion activation of plant enzymes. Jour. Biol. Chem. **73**: 405–416. *f. 1–3.* Je 1927.

Duff, G. H., & Welch, C. G. Sulphur, as a control agent for common scab of potato. Phytopathology **17**: 297–314. *f. 1.* 15 My 1927.

Durland, W. D. The pine forests of Honduras. Tropical Woods 10: 8–9. 1 Je 1927.

Edgerton, C. W., & Tims, E. C. Investigations on the sugar cane disease situation in 1925 and 1926. Louisiana Agr. Exp. Sta. Bull. 197: 1–50. *f. 1–11.* Ap 1927.

Ellsworth, H. A. Inheritance of carpel displacement. Jour. Hered. **18**: 133. *f. 19.* "Mr" 13 My 1927.

Epling, C. C. Studies on South American Labiatae. III. Synopsis of the genus *Satureia.* Ann. Missouri Bot. Gard. **14**: 47–86. 8 Je 1927.

Evans, M. W. The life history of timothy. U. S. Dept. Agr. Bull. 1450: 1–56. *f. 1–6 + pl. 1–12.* Mr 1927.

Ezell, B. D., & Crist, J. W. Effect of certain nutrient conditions on activity of oxidase and catalase. Michigan Agr. Exp. Sta. Tech. Bull. 78: 1–24. *f. 1–3.* My 1927.

Fernald, M. L. Some varieties of *Artemisia borealis.* Rhodora **29**: 93–95. "My" 6 Je 1927.

Fernald, M. L. *Streptopus oreopolus* in the White Mountains. Rhodora **29**: 76. "Ap" 2 My 1927.
Mt. Washington.

Fisher, R. T. A museum of forest antiquity. Am. For. & For. Life **33**: 348. *illust.* Je 1927.
So-called Pigsah forest in southern New Hampshire.

Fromme, F. D., Wingard, S. A., & Priode, C. N. Ringspot of tobacco: an infectious disease of unknown cause. Phytopathology **17:** 321–328. *f. 1–6.* 15 My 1927.

Fryxell, F. M. The green tree. Am. For. & For. Life **33:** 357–360. *illust.* Je 1927.
LeClaire elm in Iowa.

Gardner, N. L. New Rhodophyceae from the Pacific coast of North America. III. Univ. California Publ. Bot. **13:** 333–368. *pl. 59–71.* 12 My 1927.

Gardner, N. L. A new species of *Entophysalis* from China, and notes on other species of the genus. Univ. California Publ. Bot. **13:** 369–372. *pl. 72.* 12 My 1927.

Garrett, A. O. Spring flora of the Wasatch region. 4th ed. rev. i–iv, 1–208. Salt Lake City, Stevens and Wallis, 1927.

Gaylord, I. N. California cañon ferns. Am. Fern Jour. **17:** 61–63. 18 Je 1927.

Girton, R. E. The growth of citrus seedlings as influenced by environmental factors. Univ. California Publ. Agr. Sci. **5:** 83–117. *f. 1–8.* 15 Ap 1927.

Gleason, H. A., & Cook, M. T. Plant ecology of Porto Rico. Sci. Survey Porto Rico and the Virgin Islands 7^{1-2}: 1–173. *pl. 1–50.* 22, 25 F 1927.

Gluck, H. A new *Sagittaria* from Florida: *Sagittaria Kurziana.* Bull. Torrey Club **54:** 257–261. "Mr" 2 My 1927.

Goldstein, B. The x-bodies in the cells of dahlia plants affected with mosaic disease and dwarf. Bull. Torrey Club **54:** 285–294. *f. 1, 2 + pl. 18–20.* "Ap" 16 My 1927.

Graham, V. O. Ecology of fungi in the Chicago region. Bot. Gaz. **83:** 267–287. *f. 1–6.* 25 My 1927.

Grier, N. M., & Green, S. A. A phaenological note on the flora of the vicinity of Cold Spring Harbor, N. Y. Ohio Jour. Sci. **27:** 138–142. 31 My 1927.

Gundersen, A. Families of vascular plants (except dicotyledons). Brooklyn Bot. Gard. Leaflet 15^4: 1–4. 11 My 1927.

Gustafson, F. G. Plant distribution as affected by the hydrogen-ion concentration of the soil. Papers Michigan Acad. Sci. **6**: 237–246. Mr 1927.

Haas, A. R. C. Relation between fruit size and abscission of young orange fruits. Bot. Gaz. **83**: 307–313. 25 My 1927.

Harms, H. Araliaceae americanae novae. I. Repert. Spec. Nov. Reg. Veg. **23**: 299–301. 20 Mr 1927.

Harris, G. H. The activity of apple and filbert roots especially during the winter months. Proc. Am. Soc. Hort. Sci. **23**: 414–422. *f. 1–6.* "1926" 1927.

Harter, L. L., & Whitney, W. A. Relation of soil temperature and soil moisture to the infection of sweet potatoes by the stem-rot organism. Jour. Agr. Res. **34**: 435–442. *f. 1, 2.* 1 Mr 1927.

Harter, L. L., & Whitney, W. A. A transit disease of snap beans caused by *Pythium aphanidermatum*. Jour. Agr. Res. **34**: 443–448. *pl. 1.* 1 Mr 1927.

Harvey, J. V. *Brevilegnia diclina* n. sp. Jour. Elisha Mitchell Sci. Soc. **42**: 243–246. *pl. 44, 45.* My 1927.

Hein, I. Studies on morphogenesis and development of the ascocarp of *Sphaerotheca Castagnei*. Bull. Torrey Club **54**: 383–417. *f. 1–5 + pl. 28, 29.* "My" 18 Je 1927.

Helwig, B. Convolvulaceae austro-americanae novae. Notizbl. Bot. Gart. Berlin **9**: 1136–1138. 25 Mr. 1927.
Several species in *Jacquemontia* described as new.

Henrard, J. T. *Eragrostis triangularis* spec. nov. aus Paraguay. Repert. Spec. Nov. Reg. Veg. **23**: 301–302. 20 Mr 1927.

Hepburn, J. S., Jones, F. M., & St. John, E. Q. Biochemical studies of the North American Sarraceniaceae. Trans. Wagner Free Inst. Sci. Phila. **11**: 1–95. *illust.* Ap 1927.

Heppner, M. J. Study of Bartlett pear black-end undertaken in California. Science II. **65**: 280–281. 18 Mr 1927.

Hildreth, A. C. Determination of hardiness in apple varieties and the relation of some factors to cold resistance. Minnesota Agr. Exp. Sta. Tech. Bull. 42: 1–37. *f. 1–5.* Je 1926.

Himmel, W. J. A contribution to the biophysics of *Podophyllum* petioles. Bull. Torrey Club **54:** 419–451. *f. 1–5 + pl. 30, 31.* "My" 18 Je 1927.

Hitchcock, A. E., & Zimmerman, P. W. Variation in rooting response of cuttings placed in media in different pH value. Proc. Am. Soc. Hort. Sci. **23:** 383–390. *pl. 1, 2.* "1926" 1927.

Hitchcock, A. S. The grasses of Ecuador, Peru, and Bolivia. Contr. U. S. Natl. Herb. **24:** i–xx, 291–556. 1927.

29 species described as new.

Hitchcock, A. S. How the taxonomists may utilize the international committee on nomenclature. Science II. **65:** 412–414. 29 Ap 1927.

Hitchcock, A. S. Two new grasses from South America. Jour. Washington Acad. Sci. **17:** 215–217. *f. 1, 2.* 4 My 1927.

Olyra sampaiana and *Trisetum bulbosum.*

Hofmann, F. N. Reciprocal effects from grafting. Jour. Agr. Res. **34:** 673–676. 1 Ap 1927.

Howlett, F. S. Methods of procedure in pollination studies. Proc. Am. Soc. Hort. Sci. **23:** 107–119. "1926" 1927.

Hurst, C. C. The conception of a species. Science II. **65:** 271–273. 18 Mr 1927.

Jansson, K. P. Rayless *Aster multiflorus.* Rhodora **29:** 95. "My" 6 Je 1927.

Jeffrey, E. C. New light on evolution. Science II. **65:** 458–462. 13 My 1927.

Jenkins, A. E. Brown canker of the rose. Am. Rose Annual **1927:** 161–183. *pl. 11–19.* 1927.

Jodidi, S. L. Isolation and identification of some organic compounds occurring in etiolated corn seedlings. Jour. Agr. Res. **34:** 649–656. 1 Ap 1927.

Johnson, J. The classification of plant viruses. Wisconsin Agr. Exp. Sta. Res. Bull. **76:** 1–16. *f. 1–8.* F 1927.

Jones, H. A. Pollination and life history studies of lettuce (*Lactuca sativa* L.). Hilgardia **2**: 425–478. *pl. 1–18.* Ap 1927.

Jones, H. A., & Robbins, W. W. Influence of desiccation and root pruning on performance of *Asparagus.* Proc. Am. Soc. Hort. Sci. **23**: 26–28. "1926" 1927.

Kanehira, R. Note on the identity of the Chinese "pau-hoi." Tropical Woods **10**: 53–54. 1 Je 1927.

Karling, J. S. Variations in the mature antheridium of the Characeae: a descriptive study in morphogenesis. Bull. Torrey Club **54**: 187–230. *f. 1–13* + *pl. 10–14.* "Mr" 2 My 1927.

Keen, B. A. Some physical and physico-chemical effects of soil organic matter. Jour. Am. Soc. Agron. **19**: 362–368. My 1927.

Keim, F. D., & Beadle, G. W. Relation of time of seeding to root development and winter survival of fall seeded grasses and legumes. Ecology **8**: 251–264. *f. 1–6.* Ap 1927.

Kelley, A. P., & Shoemaker, M. B. Staining of yeast cells. Bot. Gaz. **83**: 318. 25 My 1927.

Kenoyer, L. A. Notes on Indian ruderals. Papers Michigan Acad. Sci. **6**: 247–251. Mr 1927.

Kirby, R. S. Diseases of small grains. Cornell Agr. Exp. Sta. Ext. Bull. **157**: 1–71. *f. 1–31.* Mr 1927.

Klugh, A. B., & Martin, J. R. The growth-rate of certain marine algae in relation to depth of submergence. Ecology **8**: 221–231. *f. 1–4.* Ap 1927.

Knott, J. E. Further localization of the response in plant tissue to relative length of day and night. Proc. Am. Soc. Hort. Sci. **23**: 67–70. "1926" 1927.

Knuth, R. Oxalidacearum species novae americanae. II. Repert. Spec. Nov. Reg. Veg. **23**: 275–282. 20 Mr 1927.

Korstian, C. F., & Stickel, P. W. The natural replacement of blight-killed chestnut in the hardwood forests of the northeast. Jour. Agr. Res. **34**: 631–648. *f. 1–9.* 1 Ap 1927.

Kulkarni, C. G. Inheritance studies of white-capping in Yellow Dent maize. Papers Michigan Acad. Sci. **6:** 253–273. Mr 1927.

Larsen, E. L. A revision of the genus *Townsendia*. Ann. Missouri Bot. Gard. **14:** 1–46. *pl. 1–7.* 8 Je 1927.

Lee, H. A., & Martin, J. P. A method for testing in vitro the toxicity of dust fungicides to fungous spores. Phytopathology **17:** 315–319. 15 My 1927.

Leissner, G. Nilssoń-. Relation of selfed strains of corn to F_1 crosses between them. Jour. Am. Soc. Agron. **19:** 440–454. My 1927.

Leonard, E. C. Fourteen new species of plants from Hispaniola. Jour. Washington Acad. Sci. **17:** 65–73. *illust.* 3 F 1927.

Lewis, W. F. Some Adirondack rarities. Am. Fern Jour. **17:** 37–43. 18 Je 1927.

Lloyd, F. E. Cell disjunction in *Spirogyra*. Papers Michigan Acad. Sci. **6:** 275–287. *f.* 1 + *pl. 19.* Mr 1927.

Lyon, H. L. Exotic trees in Hawaii (cont.) Hawaiian Pl. Rec. **31:** 163–169. *illusl.* Ap 1927.

Lyon, M. W., Jr. List of flowering plants and ferns in the Dunes State Park and vicinity, Porter County, Indiana. Am. Midl. Nat. **10:** 245–295. Mr–Ap 1927.

Mackenzie, K. K. *Solidago altissima* L. Rhodora **29:** 72–75. "Ap" 2 My 1927.

Mangelsdorf, A. J. Origin of the garden strawberry. Jour. Hered. **18:** 177–183. *f. 18–21.* "Ap" 7 Je 1927.

Martin, J. H., & Ratliffe, G. T. Loose kernel smut on feterita. Phytopathology **17:** 338–339. 15 My 1927.

Matzke, E. B. An analysis of the orthic tetrakaidecahedron. Bull. Torrey Club **54:** 341–348. *f. 1–6.* "Ap" 16 My 1927.

Melchior, H. Plantae Steinbachianae. II. Notizbl. Bot. Gart. Berlin **9:** 1155–1160. 25 Mr 1927.

Merrill, E. D. *Swinglea*, a new generic name in the Rutaceae. Jour. Arnold Arbor. **8:** 131–132. Ap 1927.

Mildbraed, J. Plantae Tessmannianae peruvianae. IV. Notizbl. Bot. Gart. Berlin **9:** 1139–1154. *f. 18.* 25 Mr 1927.

Genera *Tessmannianthus* and *Meiandra*, as well as many species, described as new.

Mockeridge, F. A. The auximone theory. Bot. Gaz. **83:** 314–317. 25 My 1927.

Moore, H. C. Hollow heart in potatoes. Papers Michigan Acad. Sci. **6:** 289–294. Mr 1927.

Morris, L. S., & Crist, J. W. The influence of reaction of culture medium on growth of strawberry plants. Michigan Agr. Exp. Sta. Tech. Bull. 77: 1–16. *f. 1–6.* My 1927.

Mottier, D. M. Behavior of certain fern prothallia under prolonged cultivation. Bot. Gaz. **83:** 244–266. *f. 1–7* + *pl. 10.* 25 My 1927.

Munz, P. A. The southern California species of *Salvia* (including *Ramona*). Bull. So. California Acad. Sci. **26:** 17–29. *pl. 3, 4.* Ja–Ap 1927.

Murray, C. D. A relationship between circumference and weight in trees and its bearing on branching angles. Jour. Gen. Physiol. **10:** 725–729. *f. 1, 2.* 20 My 1927.

Nelson, A. Taxonomic studies. 1. The loco plants. 2. Miscellaneous new species. Univ. Wyoming Publ. Sci. **1:** 109–143. *f. 7.* 15 Mr 1926.

In *Chenopodium, Allium, Zygadenus, Delphinium, Phlox, Pentstemon, Machaeranthera, Antennaria, Gaillardia, Lessingia, Actinea* and *Senecio.*

Oskamp, J. Soil moisture and tree growth relationships. Proc. Am. Soc. Hort. Sci. **23:** 269–277. "1926" 1927.

Ostenfeld, C. H. The flora of Greenland—its origin. K. Danske Vidensk. Sels. Biol. Meddel. **6^3:** 1–71. *f. 1–3.* 22 N 1926.

Overholser, E. L. Apple pollination studies in California. California Agr. Exp. Sta. Bull. 426: 1–17. My 1927.

Owen, F. V. Hereditary and environmental factors that produce mottling in soy beans. Jour. Agr. Res. **34:** 559–588. *f. 1–4* + *pl. 1.* 15 Mr 1927.

Parodi, L. R., & Thellung, A. *Alopecurus bonariensis* Parodi et Thell. spec. nov. Repert. Spec. Nov. Reg. Veg. **23**: 302–303. 20 Mr 1927.

Payson, E. B. *Thlaspi*, *Oreocarya*, and *Erigeron*. Univ. Wyoming Publ. Sci. **1**: 145–186. *f. 8–16.* 15 Mr 1926.

1. The genus *Thlaspi* in North America. 2. *Oreocarya*. 3. *Erigeron compositus* and its allies in the United States.

Peattie, D. C. *Trillium* in North and South Carolina. Jour. Elisha Mitchell Sci. Soc. **42**: 193–206. My 1927.

Philp, G. L. Some pollination difficulties in cherry production. Proc. Am. Soc. Hort. Sci. **23**: 28–30. "1926" 1927.

Pickett, F. L., & Thayer, L. A. The gametophytic development of certain ferns: *Polypodium vulgare* var. *occidentale* and *Pellaea densa*. Bull. Torrey Club **54**: 249–255. *pl. 15–17.* "Mr" 2 My 1927.

Pittier, H. The Lecythidaceae of Central America. Contr. U. S. Nat. Herb. **26**: 1–14. *pl. 1–12.* 1927.

11 species described as new.

Quisenberry, K. S. Correlated inheritance of quantitative and qualitative characters in oats. West Virginia Agr. Exp. Sta. Bull. 202: 1–55. *f. 1–4.* Jl 1926.

Record, S. J. The editor again visits Central America. Tropical Woods 10: 1–3. 1 Je 1927.

Record, S. J. Trees of Hunduras. Tropical Woods 10: 10–47. 1 Je 1927.

Reed, G. M., Swabey, M., & Kolk, L. A. Experimental studies on head smut of corn and sorghum. Bull. Torrey Club **54**: 295–310. *pl. 21–25.* "Ap" 16 My 1927.

Rehder, A. Charles Sprague Sargent. Jour. Arnold Arbor. **8**: 69–86. *port.* Ap 1927.

Born 24 Ap 1841. Died 22 Mr 1927.

Ricker, P. L. Give the wild flowers a chance. Nat. Mag. **9**: 303–306. *6 col. pl.* My 1927.

Ripperton, J. C. Carbohydrate metabolism and its relation to growth in the edible canna. Hawaii Agr. Exp. Sta. Bull. 56: 1–35. *f. 1–17.* My 1927.

Robbins, W. W., & Jones, H. A. Sex as a factor in growing asparagus. Proc. Am. Soc. Hort. Sci. **23**: 19–23. *f. 1.* "1926" 1927.

Roberts, J. W., & Dunegan, J. C. Peach brown rot and scab. U. S. Dept. Agr. Farmers Bull. 1527: 1–14. *f. 1–6.* Ap 1927.

Rosa, J. T. Direct effects of pollen on fruit and seeds of melons. Proc. Am. Soc. Hort. Sci. **23**: 243–249. "1926" 1927.

Rose, J. N. Professor D. Carlos Spegazzini 1858–1926. Jour. N. Y. Bot. Gard. **28**: 118–119. My 1927.

Rusby, H. H. Additions to the genus *Munnozia* R. and P. Bull. Torrey Club **54**: 311–320. "Ap" 16 My 1927.

Rydberg, P. A. Notes on Fabaceae—IX. Bull. Torrey Club **54**: 321–336. "Ap" 16 My 1927.

Several species in *Hamosa*, described as new.

Salter, F. J. The chemical composition of soil organic matter as related to its effectiveness. Jour. Am. Soc. Agron. **19**: 397–409. My 1927.

Sandwith, N. Y. New species from the Andes of Argentina. Kew Bull. Misc. Inf. **1927**: 174–188. *pl. 1.* 1927.

In *Berberis*, *Malvastrum*, *Cristaria*, *Larrea*, *Anarthrophyllum*, *Adesmia*, *Cassia*, *Chuquiragua*, *Calceolaria*, *Argylia*, and *Verbena*.

Sarton, G. Introduction to the history of science. vol. 1. From Homer to Omar Khayyam. Carnegie Inst. Washington Publ. 376: 1–839. 1927.

Schaffner, J. H. Additions to the catalog of Ohio vascular plants for 1926. Ohio Jour. Sci. **27**: 95–101. 29 Ap 1927.

Schaffner, J. H. Sex-limited characters and allosome-linked heredity. Ohio Jour. Sci. **27**: 105–126. 31 My 1927.

Schaffner, J. H. Spiral shoots of *Equisetum*. Am. Fern Jour. **17**: 43–46. *pl. 2.* 18 Je 1927.

Schmidt, O. C. Beiträge zur Kenntnis der Aristolochiaceen. I. Repert. Spec. Nov. Reg. Veg. **23:** 282–299. 20 Mr 1927.

Shamel, A. D., Pomeroy, C. S., & Caryl, R. E. Bud selection in the Washington navel orange. Jour. Hered. **18:** 135–142. *f. 20–22.* "Mr" 13 My 1927.

Shantz, H. L. Drought resistance and soil moisture. Ecology **8:** 145–157. Ap 1927.

Shuhart, D. V. The morphological differentiation of the pistillate flowers of the pecan. Jour. Agr. Res. **34:** 687–696. *f. 1–5 + pl. 1–6.* 1 Ap 1927.

Sigler, D., & Woollett, M. L. An ecological study of Hogback Bog, Cheboygan County, Michigan. Papers Michigan Acad. Sci. **6:** 295–302. *f. 1 + pl. 20.* Mr 1927.

Small, J. K. The palmetto-palm—*Sabal texana.* Jour. N. Y. Bot. Gard. **28:** 132–143. *f. 3–5.* Je 1927.

Biographical notes by John Hendley Barnhart.

Standley, P. C. The flora of Barro Colorado Island Panama. Smithsonian Inst. Misc. Coll. **78:** 1–32. 20 My 1927.

Standley, P. C. New or otherwise interesting trees and shrubs collected in Guatemala and Honduras in 1927 by Samuel J. Record and Henry Kuylen. Trop. Woods 10: 4–7. 1 Je 1927.

In *Coccoloba, Ruprechtia, Abutilon, Grislea, Tococa, Diospyrros* and *Rondeletia.*

Standley, P. C. New trees collected in Panama by George P. Cooper and George M. Slater. Trop. Woods 10: 47–51. 1 Je 1927.

In *Carapa, Meliosma, Cilharexylum, Cyphomandra.*

Stanford, E. E. *Polygonum hydropiper* in Europe and North America. Rhodora **29:** 77–87. "My" 6 Je 1927.

Steward, A. N. The *Hepatica transsilvanica* group of eastern Europe and Asia. Rhodora **29:** 53–54. "Ap" 2 My 1927.

Swartwout, H. G. Blister and black rot cankers. Mis Agr. Exp. Sta. Bull. 248: 1–15. *f. 1–13.* Mr 1927.

Swingle, C. F. Burrknot formations in relation to the vascular system of the apple stem. Jour. Agr. Res. **34:** 533–544. *f. 1–4* + *pl. 1–5*. 15 Mr 1927.

Swingle, C. F. A quantitative study of the effects of transplanting and of budding upon the growth of apple seedlings. Proc. Am. Soc. Hort. Sci. **23:** 99–104. "1926" 1927.

Taylor, N. Age and area. Ecology **8:** 283–284. Ap 1927.

Taylor, W. P. Ecology or bio-ecology. Ecology **8:** 280–281. Ap 1927.

Tharp, B. C. *Commelinantia Pringlei.* Bull. Torrey Club **54:** 337–340. *pl. 26, 27.* "Ap" 16 My 1927.

Thomas, W. The nitrogenous metabolism of *Pyrus malus.* Proc. Am. Soc. Hort. Sci. **23:** 73–80. *f. 1.* "1926" 1927.

Tiedjens, V. A. Some observations on root and crown bud formation in *Asparagus officinalis.* Proc. Am. Soc. Hort. Sci. **23:** 189–196. "1926" 1927.

Tiedjens, V. A. Some observations on the response of greenhouse cucumbers (*Cucumis sativa*) to certain environmental conditions. Proc. Am. Soc. Hort. Sci. **23:** 184–189. "1926" 1927.

Tiffany, L. H. The algal collection of a single fish. Papers Michigan Acad. Sci. **6:** 303–306. Mr 1927.

Todd, J. B. The finding of *Woodsia obtusa.* Am. Fern Jour. **17:** 57–59. 18 Je 1927.

Traub, H. P. The regional and seasonal distribution of moisture and food in 2–3 years apple twigs. Proc. Am. Soc. Hort. Sci. **23:** 127–131. *f. 1, 2.* "1926" 1927.

Trelease, W. *Agave* novae hispaniolenses. Repert. Spec. Nov. Reg. Veg. **23:** 362–363. 20 Mr 1927.

Trelease, W. Piperaceae hispaniolenses. Repert. Spec. Nov. Reg. Veg. **23:** 303–333. 20 Mr 1927.

Trelease, W. The Piperaceae of Panama. Contr. U. S. Nat. Herb. **26:** i–viii, 15–50. 1927.

Tucker, C. M. Pigeon pea anthracnose. Jour. Agr. Res. **34:** 589–596. *f. 1–3.* 15 Mr 1927.

Victorin, Marie- (Frère). Les Filicinées du Québec. Revue Triméstrielle Canad. Suppl. **9:** 1–98. Mr 1923.
(Contr. Lab. Bot. Univ. Montréal 2.)

Victorin, Marie- (Frère). Les Lycopodinées du Québec. Contr. Lab. Bot. Univ. Montréal 3: 1–121. *f. 1–11 + pl. 1.* 21 My 1925.

Victorin, Marie- (Frère). Études floristiques sur la région du lac Saint-Jean. Contr. Lab. Bot. Univ. Montréal 4: 1–74. *f. 1–28.* 1925.

Victorin, Marie- (Frère). Random botanical notes. L'Islet County, Quebec. Ottawa Naturalist 32: 109–111. 1918.

Victorin, Marie- (Frère). Note sur une florule halophytique-côtière reliquale dans le bassin du lac Saint-Jean. Proc. Trans. Roy. Soc. Canada III. **19**^{1}: 97–108. 1925.

Victorin, Marie- (Frère). Sur quelques Composées nouvelles, rares ou critiques du Québec oriental. Proc. Trans. Roy. Soc. Canada III. **19**^{1}: 79–96. *f. 1–3 + pl. 1–4.* 1925.
Cirsium minganense, and several varieties, described as new.

Victorin, Marie- (Frère). Notes sur quelques cas de teratologie végétale. Proc. Trans. Roy. Soc. Canada III. **20**^{5}: 427–433. *f. 1, 2 + pl. 1.* 1926.

Victorin, Marie- (Frère). Notes pour servir à l'histoire de nos connaissances sur les Abiétacées du Québec. Proc. Trans. Roy. Soc. Canada III. **20**^{5}: 437–460. *f. 1 + pl. 1–3.* 1926.

Victorin, Marie- (Frère). Nouvelles études sur les Composées du Québec. Proc. Trans. Roy. Soc. Canada III. **20**^{5}: 461–482. *f. 1–3 + pl. 1–4.* 1926.
Several varieties and hybrids described as new.

Walpole, B. A. Distribution of the Cruciferae in Michigan. Papers Michigan Acad. Sci. **6:** 307–349. Mr 1927.

Waterman, W. G. Ecology of Glen Lake and Sleeping Bear region. Papers Michigan Acad. Sci. **6:** 351–376. *f. 1 + pl. 21–32.* Mr 1927.

Waters, C. E. A suburban fern bed. Am. Fern Jour. **17:** 52–57. Je 1927.

Webber, H. J. Rootstock reactions as indicating the degree of congeniality. Proc. Am. Soc. Hort. Sci. **23:** 30–36. *f. 1.* "1926" 1927.

Wehmeyer, L. E. Cultural life-histories of *Diaporthe.* I. Papers Michigan Acad. Sci. **6:** 377–396. *pl. 33–36.* Mr 1927.

Weimer, J. L. A wilt disease of alfalfa caused by *Fusarium* species. Phytopathology **17:** 337–338. 15 My 1927.

Weir, J. R. Butt rot in *Diospyros virginiana* caused by *Polyporus Spraguei.* Phytopathology **17:** 339–340. 15 My 1927.

Wester, P. J. Introduction of Manila hemp. Jour. Hered. **18:** 117–118. *f. 9–11.* "Mr" 13 My 1927.

Wherry, E. T. Divergent soil reactions of related plants. Ecology **8:** 197–206. Ap 1927.

Wherry, E. T. A fernless area. Am. Fern Jour. **17:** 63–64. 18 Je 1927.

Brownsville, Texas.

White, C. T. A previously undescribed species of *Maniltoa* from Papua. Jour. Arnold Arbor. **8:** 130. Ap 1927.

M. lenticellata.

Wiggans, C. B. A suggestion of a safer method for determining the relative value of cross and self-pollination in the apple. Proc. Am. Soc. Hort. Sci. **23:** 297–298. *f. 1.* "1926" 1927.

Wingard, S. A. The immediate effect of cross-pollination on the size and shape of bean seed. Genetics **12:** 115–124. *f. 1–3.* "Mr" 10 Je 1927.

Winkler, A. J. Some factors influencing the rooting of vine cuttings. Hilgardia **2:** 329–349. *f. 1–11.* Ja 1927.

Wister, J. C. The Iris; a treatise on the history, development and culture of the Iris. 1–122. *illust.* N. Y., Orange Judd Co., 1927.

Wolfe, T. K. A study of germination, maturity and yield in corn. I. The relation of kernel characters and environmental factors to the germination of corn. II. The relation between kernel characters and the maturity and yield of the corn plants produced from particular kinds of kernels. Virginia Agr. Exp. Sta. Tech. Bull. 30: 1–35. *f. 1.* Ja 1927.

Woodcock, E. F. Morphological studies of the seed of *Alsine media.* Papers Michigan Acad. Sci. **6**: 397–403. *pl. 37–38.* Mr 1927.

Woodworth, R. H. Interesting plants of northern Labrador. Rhodora **29**: 54–57. "Ap" 2 My 1927.

Wright, A. H., & Wright, A. A. The dwarf bearded Iris. I. A preliminary working list. Cornell Agr. Exp. Sta. 1–12. 4 F 1927.

York, H. H., Snell, W. H., & Rathbun-Gravatt, A. The results of inoculating *Pinus strobus* with the sporidia of *Cronartium ribicola.* Jour. Agr. Res. **34**: 497–510. *f. 1–3 + pl. 1.* 15 Mr 1927.

Zeller, S. M. A canker of apple and pear trees caused by *Glutinium macrosporium* n. sp. Jour. Agr. Res. **34**: 489–496. *f. 1–10.* 1 Mr 1927.

Zeller, S. M. Preliminary studies on witches' broom of strawberry. Phytopathloogy **17**: 329–335. *f. 1–4.* 15 My 1927.

Zerbee, F. B. A miniature greenhouse. Nat. Mag. **9**: 377–378. *illust.* Je 1927.

A Wardian case.

Soil temperatures in redwood and hemlock forests

FORREST SHREVE

During the latter part of the summer of 1925 an investigation was made of the soil temperature conditions within and just outside an area of redwood forest in the Santa Lucia Mountains, California. Readings were secured under natural conditions, under conditions of removal of litter of leaves in the forest, and also under conditions produced by using the forest litter as a cover for bare ground in openings in the forest. The investigation of unforested areas included one near the forest, in the floor of a canyon, and one on the summit of an adjacent ridge. In the following winter the writer found that Mr. Freeman Weis, of the United States Department of Agriculture, had secured a series of soil temperature readings over nearly the same period in a mature stand of hemlock near Freeland, Pennsylvania. Mr. Weis very generously provided the writer with a copy of his data for comparison and publication. The present paper embodies the California data, the Pennsylvania data, and such comparison as is possible.

All of the figures presented were secured with the Friez thermograph, calibrated before and after use, and checked monthly during use. The means and extremes have been read from the thermograph slips. All data are given in Fahrenheit degrees. In the California series the data were secured at depths of 3 inches and 12 inches, in the Pennsylvania series only at 3 inches. Readings under natural conditions were taken with as little disturbance of the surface as possible. Removal of the natural litter in the redwood forest was done so as to take all loose leaves, and all blackened but loosely placed leaves. The level at which the remains of blackened leaves form a fairly compact layer was left undisturbed, and this level was in all cases used as the datum for setting the cylinder of the

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thermograph at a given depth. The material used to form a mulch over the bare surface of the unforested area was the same as that removed in the forest. It was placed on the ground in as natural a manner as possible, to a depth of 5 inches, with the blackened material beneath, and freshly fallen twigs on top, the area covered being 100 square feet, with the thermograph bulb at the center.

The readings in redwood forest were taken in the floor of Rocky Creek canyon, 12 miles south of Carmel, California, and about one mile from the spot at which this stream debouches into the sea. The readings in the opening were taken about 600 feet from the forest station, in a spot bare of perennial vegetation and not shaded by trees between 8 a.m. and 5 p.m. There is no apparent reason why the opening should not form a successful habitat for the redwood. The ridge readings were taken on Long Ridge, about 1200 feet above the elevation of the other stations, and about one-half mile distant. The ridge is without perennial vegetation at this spot and is covered during the summer with the inactive or dead grasses and herbaceous plants which appear during the spring rains. In this region redwood forest is never found occupying the summits of ridges, and only occasional groves of small, wind-blown trees are found on the upper slopes. A fuller description of the area investigated and of its vegetation has been published elsewhere.[1]

TABLE I

Soil temperature at depth of 3 inches in hemlock forest near Freeland, Pennsylvania

WEEK ENDING —1925	MEAN		ABS.		WEEK ENDING	ABS.		WEEK ENDING	ABS.	
	max.	min.	max.	min.		max.	min.		max.	min.
May 23	45	43	46	41	July 4	52	48	Aug. 15	54	52
May 30	44	42	49	40	July 11	56	49	Aug. 22	55	51
June 6	50	47	53	44	July 18	55	50	Aug. 29	54	49
June 13	52	50	53	47	July 25	54	50	Sept. 5	53	49
June 20	52	50	54	49	Aug. 1	53	50	Sept. 12	56	51
June 27	—	—	51	48	Aug. 8	53	50	Sept. 19	57	51

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[1] Shreve, Forrest. The Vegetation of a Coastal Mountain Range. Ecology **8**: 27–44. *f. 1–6.* 1927. Shreve, Forrest. The Physical Conditions of a Coastal Mountain Range. Ecology **8**: 398–414. 1927.

The coastal redwood forests present ideal conditions for the maintenance of extremely uniform soil temperatures. Given the equable marine climate, the heavy shade of the great trees, and the depth of the litter with which the ground is covered, and the combined effect is a remarkably stabilizing one.

The readings taken by Mr. Weis at a depth of 3 inches in a mature stand of hemlock (*Tsuga canadensis*) near Freeland, Luzerne County, Pennsylvania, are shown in TABLE 1. The records extend from May 16 to September 19, 1925. The record is characterized throughout by an extremely small daily range. For the five weeks from May 16 to June 20 the mean weekly range was 2.2° for the soil, as compared with 15.0° for the air, and the absolute weekly range was 6.8°, as against 43° for the air. For the succeeding 13 weeks the absolute weekly range was 4.1°. The absolute weekly maximum temperature rose almost continuously from 46° in the week of May 16 to 56° in the week of July 11, and remained within 4° of the same value until the middle of September, reaching the highest value for the summer at 57° on the week ending September 19. The weekly absolute minimum for the entire record ranged from 40° to 52°, but during the principal part of the summer it varied only through a range of 4°. The weekly absolute maximum

TABLE 2

Soil temperature at depth of 3 or 12 inches in redwood forest near Carmel, California, with and without natural mulch of leaves

CONDITION OF SURFACE	DEPTH	WEEK ENDING	AVERAGE		ABSOLUTE	
			max.	min.	max.	min.
Natural cover	3 in.	July 21, '25	59.1	56.5	60.0	55.6
" "	3 in.	July 28	59.0	57.5	59.9	56.9
" "	3 in.	Aug. 4	59.4	58.0	59.9	57.4
" "	3 in.	Aug. 11	59.4	57.4	60.0	57.0
" "	3 in.	Aug. 18	59.1	57.1	60.0	55.9
Natural cover removed	3 in.	Aug. 26	59.7	55.4	60.0	54.8
" " "	3 in.	Sept. 2	58.9	55.2	59.5	54.0
" " "	3 in.	Sept. 9	61.4	56.6	62.3	55.1
" " "	3 in.	Sept. 15	60.3	57.0	61.5	55.0
Natural cover	12 in.	Sept. 22	58.8	58.7	60.0	57.7
" "	12 in.	Sept. 29	58.3	57.9	59.0	57.0
" "	12 in.	Oct. 6	57.5	57.1	58.2	56.1
" "	12 in.	Oct. 13	57.3	56.9	57.8	56.8

temperatures of the air ranged from 66° to 82° for the period of the record, and the weekly absolute minimum temperature from 32° to 56°.

The readings taken in a virgin stand of redwood (*Sequoia sempervirens*) near Carmel, California, are shown in TABLE 2. Readings taken at 3 inches under the natural cover of fallen leaves were secured during the last two weeks of July and the first three weeks of August, and again at 12 inches during the last half of September and the first half of October. The highest maximum recorded at 3 inches was 60.0° and the lowest minimum was 55.6°. The average daily maximum for the five weeks was 59.2° and the average daily minimum 57.3°, giving a mean daily range of 1.9°. In order to compare the California and Pennsylvania records it is necessary to determine the average of the weekly absolute maximum and minimum for the five weeks in which the records were taken under comparable conditions. For the redwood forest the values are: average absolute maximum 60.0°, average absolute minimum 56.5°. The corresponding figures for the hemlock forest are 53.8° and 50.4°. The range between these rather awkward expressions of the extremes is 3.5° for the redwood forest and 3.4° for the hemlock. In short, the actual temperature at 3 inches under redwoods is about 6° higher than it is under hemlocks, growing 2500 miles distant, and the weekly range of temperature is virtually identical for the two forests.

After records had been secured at 3 inches in the redwood forest for five weeks, under normal conditions, the natural mulch of fallen twigs and leaves was removed to a depth of five inches without change in the thermograph. Records were secured for four weeks without the mulch. The average weekly maximum for the period, with normal cover, was 59.2, the average weekly minimum 57.3°. For the period with cover removed the same data were respectively 60.1° and 56.0°. The very slight difference due to removal of the mulch is in the expected direction of elevating the maximum and lowering the minimum. The difference is so small as to have little significance, however, even in a realm where small differences of temperature are more important than they are in the air.

The records secured at a depth of 12 inches under the natural mulch of leaves, over a period of four weeks, show little difference from those taken at a depth of 3 inches. The graphs taken at the greater depth are very flat, the minimum for the day occurring at 1 to 2 p.m. and the maximum at about midnight. The average maximum was 1.2° lower than at 3 inches, and the average minimum 0.3° higher.

Records were taken in the opening in the redwood forest at 3 inches, with the natural nearly bare surface, for three weeks, and for the same period with a mulch of redwood leaves 5 inches thick. Records were also secured at 12 inches for two weeks with natural surface and for two weeks with the mulch of leaves. The resulting data are given in TABLE 3, together with the average weekly maximum and minimum under the four sets of conditions. At 3 inches the effect of the leaf mulch was to lower the average maximum 10.9°, while the average minimum remained nearly the same. At 12 inches the average maximum was lowered 5.4°, and the average minimum was also lowered 4.1°. It is to be expected that protection from active nocturnal radiation provided by the mulch would cause a higher minimum at a slight depth. At 12 inches, however, a depth at which the effect of radiation is not strongly exerted, the mini-

TABLE 3

Soil temperature at depth of 3 or 12 inches in open area in redwood forest near Carmel, California, without and with mulch of leaves from redwood forest

CONDITION OF SURFACE	DEPTH	WEEK ENDING	AVERAGE		ABSOLUTE	
			max.	min.	max.	min.
Natural bare state	3 in.	July 28, '25	77.5	64.3	81.5	61.0
" " "	3 in.	Aug. 4	82.3	67.8	85.0	66.5
Mulch of leaves on	3 in.	Aug. 18	70.8	66.9	74.0	65.0
Natural bare state	3 in.	Aug. 26	86.2	63.0	87.0	56.5
Mulch of leaves on	3 in.	Sept. 2	72.3	65.3	79.1	64.0
" " " "	3 in.	Sept. 9	70.3	64.0	71.4	62.0
Natural bare state	12 in.	Sept. 22	66.0	63.4	67.9	62.0
" " "	12 in.	Sept. 29	66.1	63.8	66.5	63.2
Mulch on leaves on	12 in.	Oct. 6	61.8	60.3	64.1	59.1
" " " "	12 in.	Oct. 13	59.6	58.8	60.3	57.6
Average 3 wks. without mulch, at 3 in.			82.0	65.0	84.5	61.3
Average 3 wks. with mulch at 3 in.			71.1	65.4	74.8	63.7
Average 2 wks. without mulch, at 12 in.			66.1	63.6	67.2	62.6
Average 2 wks. with mulch, at 12 in.			60.7	59.5	62.2	58.3

mum is lowered on account of the very much lower range of temperature of the superficial layers of soil during the day.

It is of interest to compare the temperatures in the forest with those in the opening, as taken under the natural conditions of the two localities. Considering the 3 inch data for the 2 weeks ending July 28, and August 4, the average maximum in the forest was 59.2° and in the opening 79.9°, while the average minimum was 57.7° in the forest and 66.0° in the opening. A difference of 20.7° in the maxima and 8.3° minima is indicated. A range of 1.5° in the forest is contrasted with one of 13.9° in the opening. At the 12 inch depth the average maximum in the forest was 58.6° and in the opening 66.0°, the average minima were respectively 58.3° and 63.6°. At this depth there is a smaller difference between the maxima, 7.4°, and the minima, 4.9°.

TABLE 4

Soil temperature at depth of 3 or 12 inches in open grass on ridge overlooking redwood forest, near Carmel, California

CONDITION OF SURFACE	DEPTH	WEEK ENDING	AVERAGE		ABSOLUTE	
			max.	min.	max.	min.
Natural cover	3 in.	Aug. 4, '25	95.1	73.9	99.9	72.9
" "	3 in.	Aug. 11	94.4	74.4	98.0	71.9
" "	3 in.	Sept. 2	93.0	72.5	97.9	70.0
" "	3 in.	Sept. 9	87.5	68.2	93.0	64.0
" "	3 in.	Sept. 15	78.4	62.4	84.0	58.6
" "	12 in.	Sept. 22	71.6	70.7	72.1	70.0
" "	12 in.	Sept. 29	72.9	71.7	73.0	71.1
" "	12 in.	Oct. 6	70.6	69.8	71.6	69.0
" "	12 in.	Oct. 13	67.7	66.9	70.0	63.2
Average, 5 weeks at 3 in.			89.7	70.3	94.6	67.5
Average, 4 weeks at 12 in.			70.7	69.8	71.7	68.3

Since the difference between the average maxima at 3 inches in forest and opening is 20.7° and the difference between the maxima in the open with and without mulch is 10.9°, it appears that a 5 inch mulch of leaves will bring the maximum soil temperature of an opening half way back to the temperature of the forest soil.

The readings taken on an open ridge are shown in TABLE 4, covering five weeks at 3 inches and four weeks at 12 inches.

Owing to accidental failure to secure a continuous series of records, there is only one week in which the ridge record and that in the opening were taken simultaneously. During the five weeks from July 28 to September 15 the average maximum on the ridge was 89.7° and the average minimum 70.3°. This maximum is 7.7° higher than the average for three weeks in the opening, although in the simultaneous records of the week ending August 4 the average maximum for the ridge was 12.8° above that for the opening, and 35.7° above that for the redwood forest. The average minimum for the week ending August 4 was 6.6° higher on the ridge than in the opening, and 16.4° higher on the ridge than in the forest. With respect to the temperature at 12 inches the average maxima for the two weeks ending September 22 and 29 were 72.2° for the ridge, 66.0° for the opening, and 58.5° for the forest. The average minima for the same stations for the same period are respectively 71.2°, 63.6°, and 58.3°.

The establishment of a forest in an unforested locality requires the existence of an initial set of conditions favorable to seedling trees. During the course of its growth and development a newly established forest will modify many of the environmental conditions in such a direction as to make them more favorable for the adult trees of the mature forest. This reciprocal effect of vegetation upon its own environment is, of course, true of any of the closed types of vegetation. High temperature of the soil is one of the unfavorable conditions encountered in the spread of redwood forest onto new ground within its distributional area. Under natural conditions the forest spreads only by invasion of other established communities in which the conditions have already been ameliorated to a great extent. In any efforts at reforestation with redwood it will be necessary to provide some natural or artificial set of ameliorating agencies. The difference that has been shown to exist between the soil temperatures in the forest and in a nearby opening may well be a critical one for young redwoods. The conditions which result in high soil temperatures and a greater daily range are also the ones that favor rapid drying of the soil and other features hostile to the success of seedling trees.

The differences between the temperatures in the opening and on the ridge, one-half mile distant and 1200 feet higher, are due to a series of topographic and climatic conditions on which the vegetation has had extremely little influence in either locality. There is no reason to believe that the soil temperature conditions of the opening could not be made to correspond to those of the forest if such conditions came about as to make possible the gradual steps for development of the forest at that place. It has been shown that a mulch of leaves and twigs, closely similar to that which covers the floor of the forest, will do much to bring the soil temperatures of the opening down toward those of the forest. If heavy shade were added to the mulch the change would doubtless be nearly complete. It remains very doubtful whether the ameliorating effects of the forest cover could be initiated and carried on, in this region, far enough to bring the conditions of the ridge within the range of possible soil temperatures for the growth of the redwood. Even mulch and shade would doubtless fail to reduce the maxima of the late summer to any such extent as 35.7°, the amount by which the ridge and forest maxima have been shown to differ.

Much careful work will be required on the optimum and limiting temperatures for growth of redwood roots before we are in a position to use soil temperature data, in conjunction with others, in determining the advisability of efforts toward reforestation or afforestation in a given locality.

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A cytological and a genetical study of Petunia—I

MARGARET C. FERGUSON

(WITH A TEXT FIGURE AND PLATES 35, 36)

INTRODUCTION

Since the fall of 1919 the genus *Petunia* has been continuously studied at Wellesley College by the undergraduate students in the regular course in Cytology and Genetics, by several candidates for the M.A. degree and by the writer.

Preliminary studies were made on seven cultivated strains and two wild species. From these, four forms were selected for more intensive study. These include three cultivated strains and one natural species—population 6, white; population 8, very deep purple; population 13, pink; and *Petunia nyctaginiflora* Juss., population 14, white. The seeds of the last named species were sent to us by Professor L. R. Parodi of the University of Buenos Aires, South America. There has not been the slightest suggestion of impurity, as regards color or shape of flower, either in the plants grown directly from this seed or in subsequent generations. Professor Parodi also very kindly sent us seed of the supposedly wild *P. violacea* Lind., but the plants grown from this seed showed marked variability in flower color. This seed may have been the result of crossing in nature. But we had no way of determining the earlier genetical history of this strain and, as it very evidently was not a pure form of *P. violacea* Lind., this population was discarded.

In our efforts to secure wild species of *Petunia*, we have corresponded with a number of botanists who were travelling in South America, with government officials, and with botanic gardens and seed houses in four different countries. As yet *P. nyctaginiflora* Juss. is the only natural species which we have succeeded in obtaining. Dr. Arthur W. Hill, F. R. S., Director of the Royal Botanic Gardens at Kew, England, has twice most kindly sent us plants of *P. violacea* Lind., but after the delay necessitated by government inspection at Washington, no single one of these plants has reached Wellesley alive.

By all tests available three of the four forms which we have under consideration are now homozygous for both flower color and shape of flower. The fourth form, population 13, pink, always gives some flowers, as the plants age, that are more or less flecked or spotted with white; but neither in back crosses nor in selfings for several generations has it shown any other color than the pink of the original stock.

Petunia is readily propagated by cuttings. We have, therefore, been able to have several generations of a given population under observation at the same time. Since seeds sown out of doors during the last of May give plants which are in blossom before the middle of August, it was assumed that we could secure three or four generations from seed in a given year. However, this has not been found possible. There is very little bloom from October first to December first and full blossoming vigor is not displayed before the last of February or the first of March. It has been possible to overcome somewhat the paucity of blossoms during the late fall and winter by the installation of 1000-watt, type C lamps with special reflectors in one of the 'petunia houses.' But there is also a marked seasonal sterility, so that few viable seeds are set during the period when flowers are rare. It is not our purpose to discuss at this time the phenomena of sterility or seed germination. These and other problems in the life history of *Petunia* will form the bases of later papers. To date about 25,000 plants have been grown and observed, and more than 4,000 slides of serial sections studied.

AN UNRECORDED METHOD OF 'DOUBLE FERTILIZATION'[1]

The structure of the mature embryo-sac in *Petunia* conforms very closely to the type ordinarily described for Angiosperms (PLATE 35, FIG. 1). As a rule the polar nuclei have fused before the pollen tube enters the sac, but fusion may be delayed until the growing male gametophyte has penetrated the wall of the embryo sac and extended to or beyond the egg nucleus (FIGS. 2, 3). The tip of the pollen tube reaches this position in the sac from 72 to 96 hours after pollination. When the tip of the tube has reached the level of the egg nucleus or thereabouts, but

[1] Presented before the Botanical Society of America at the Washington meeting in December, 1924.

before either sperm nucleus has been discharged from it, the endosperm nucleus divides (FIG. 4). At the close of this division a delicate wall is laid down, dividing the sac into a large basal cell and a smaller micropylar one (FIG. 5). In 1902 Guignard[1] described the early stages in the development of the endosperm in *Nicotiana* and *Datura*. He found, in both these genera, that in endosperm formation nuclear division is followed by cell division, and he concluded that in the Solanaceae there is no early free-nucleated stage in the development of the endosperm. *Petunia* is now found to be in full agreement with this generalization for the Solanaceae. Guignard's figure 43, showing the structure of an embryo sac in *Datura laevis* at the close of the first division of the endosperm, is, with the exception of the relative sizes of the two endosperm cells, practically identical with figure 5 of this paper. This figure of Guignard's is reproduced by Coulter and Chamberlain,[2] page 165. According to Guignard's interpretation, this first division of the endosperm does not occur until after 'triple fusion' and fertilization. In *Petunia*, it has been possible to demonstrate beyond question, as will appear later, that the primary division of the endosperm is completed before the sperm nuclei leave the pollen tube. It is generally stated that the sperm gives the necessary impulse for further cell division. In this case it would appear that the presence of the swollen tip of the pollen tube within the sac is sufficient stimulation to incite the development of the endosperm. In the thousands of ovules studied, no endosperm cells have ever been observed in an embryo sac prior to the entrance of the pollen tube; and in no case has a sperm nucleus been found outside the pollen tube before the division of the primary endosperm cell.

The sequence of events immediately following the division of the endosperm into two cells is not always the same. Before further mitoses take place in the endosperm, the lower sperm nucleus may escape from the tip of the tube and associate itself with the nucleus of the primary, micropylar, endosperm cell (FIGS. 6–8). At other times, before the liberation of the sperm nucleus from the pollen tube, the primary, basal, endosperm cell divides, forming a large basal cell and a much smaller upper cell. The wall separating these two cells runs parallel with the first wall laid down (FIG. 9). And in many cases, while both sperm nuclei are still within the tube, the larger, lower cell, formed as the result of the second mitosis, divides (FIG. 10). The resulting two cells are nearly equal in size, and the wall between them lies practically parallel to the two cross walls earlier formed (FIG. 11). In all cases, when the micropylar 'fusion-nucleus' is fully established or is in the early prophase of division, the endosperm consists of a tier of four cells. The uppermost cell, the primary, micropylar, endosperm cell, is always smaller than the others. The three cells below it are descendants of the primary basal cell formed at the close of the first endosperm division (FIGS. 11, 12).

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[1] Guignard, L. La double fécondation chez les Solanées. Jour. Botanique **16:** 145–167. *f. 1–45.* 1902.

[2] Coulter, J. M., and Chamberlain, C. J. Morphology of Angiosperms. New York. 1903.

The life history of the male gametophyte will be discussed in a later paper. At present I wish merely to call attention to the fact that the lower male nucleus as it lies in the tip of the tube is more or less crescent or banana shaped, though often appearing elliptical because of the view presented. It is very dense, showing little or no structure, and takes stains with great avidity (FIGS. 17a–e). As it leaves the tube and comes in contact with the upper endosperm nucleus, it increases somewhat in size (FIG. 18). There is no evidence that it enters the endosperm nucleus, but as the two press closely together, it increases in size, loses its dense appearance, and displays a more or less completely reticulated structure inclosing a comparatively large nucleolus (FIG. 19). At this stage it resembles very closely, to all appearances, the larger endosperm nucleus, with which it later becomes so closely associated that the resulting nucleus gives no structural suggestion of its dual nature (FIGS. 11, 20).

When the upper endosperm cell with its 'fusion-nucleus' divides, the wall is laid down at right angles to the walls previously formed within the embryo sac. The ensuing divisions proceed with remarkable regularity, as do the earlier divisions within the sac, and in both cases the first division is at the micropylar end, and each succeeding division occurs in the adjacent basal cell. While there may be an overlapping in the mitoses within the first four cells of the endosperm, the lower cell beginning to divide before the adjacent upper cell has fully completed its division, I have never found the four cells dividing simultaneously as shown in Guignard's figure 45 (*op. cit.*). In some hundred or more cases studied I have never found an exception, in early endosperm formation, to the series of steps shown in the accompanying diagram (TEXT FIG. 1) although, as stated above, the divisions may overlap somewhat. It will be noted (*b–e*) that each new division is in the basal cell formed by the preceding division. When anticlinal walls are laid down, they also begin at the micropylar end and move in regular succession to the base (*f–i*). Immediately following these divisions, or synchronous with them, anticlinal walls are laid down, which lie at right angles to both the horizontal walls and the longitudinal walls shown in the diagram above. Thus each of the four layers of endosperm cells is divided into four cells or quadrants (FIGS. 13, 14). Twelve of the cells resulting are the descendants of the primary, basal, endosperm cell and four are derived from the primary, micropylar, endosperm cell after its union with a sperm nucleus.

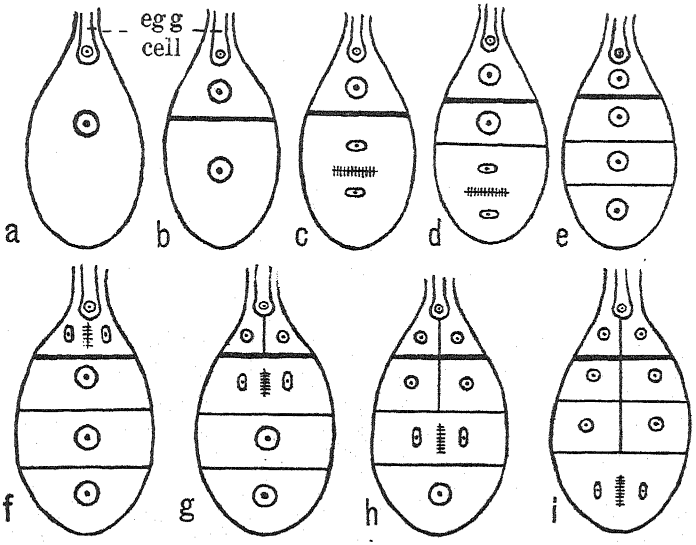

FIG. 1. Diagrammatic presentation of the steps in early endosperm formation in *Petunia*.

When the early steps in this process were first observed as in figures 4 to 7, it was assumed that the lower or basal endosperm cell would disintegrate early, and that the functional endosperm would be formed from the upper or micropylar cell. But such did not prove to be the case. On the contrary, at the 16-cell stage three fourths of the endosperm is derived from the cell that was cut off at the time of its inception from any intimate relation with the sperm. Later studies will determine whether or not from this stage on the upper tier of cells gains the ascendency in further endosperm formation. If fusion of sperm and endosperm nuclei is not an incentive to greater activity in endosperm formation, what is its significance?

The conclusion that there is no 'triple fusion,' as ordinarily described, in *Petunia*, but that the first sperm unites with the upper or micropylar cell formed by the primary division of the endosperm cell, was reached early in 1921 and further worked on in conjunction with Betty Watt (Mrs. S. T. Brooks) in 1923, and with Priscilla Presbrey in 1925. It was thought that this unusual procedure in nuclear fusions within the embryo sac of *Petunia* might be a peculiarity of cultivated forms only, since it was first observed in population 8, deep purple, and in population 6, white. But it was later found that the same method was also followed in *P. nyctaginiflora* Juss., and in hybrids between these plants (see description of plates). If this interpretation regarding nuclear fusions within the embryo sac be correct, it should easily be checked up by chromosome counts. This, however, did not prove to be so simple a matter, for while mitotic figures are frequently observed in the endosperm, they have rarely been found in stages favorable for counting chromosomes with absolute certainty. Publication has been deferred until division stages clearly revealing chromosome number at the two critical points should be observed. Figure 15 leaves no doubt as to the number of chromosomes. Fourteen chromosomes are clearly shown, so arranged as to, at least, suggest two groups of seven each. This represents a cross section of a spindle just as the chromosomes are assembling to form the equatorial plate stage in the second division of the basal endosperm cell. This mitotic figure has practically the same position in the embryo sac as has the spindle shown in figure 10.

In figure 16 the chromosomes are found more closely massed than in figure 15, but still there can be no doubt that there are 21 chromosomes present. This is the figure presented by a dividing nucleus in the primary, micropylar, endosperm cell which has virtually the same position in the embryo sac as the slightly earlier stage shown in figure 12. Since the x number of chromosomes in *Petunia* is seven, and the nuclei derived from the primary, *basal*, endosperm cell carry double that number rather than $3x$, it follows that 'triple fusion' as ordinarily described does not occur. On the other hand, the first division of the primary, *micropylar*, endosperm cell shows 21 chromosomes, the number to be expected if the uppermost endosperm nucleus fused with a sperm or other nucleus. These facts as to chromosome number, together with the series of events outlined earlier in this paper, lead to no other conclusion than that the sperm nucleus first to leave the pollen tube fuses, not with the polar nuclei, but rather with the nucleus of the micropylar daughter cell of the primary endosperm cell.

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Description of plates 35, 36

All the figures have been reduced one-half from the size of the original drawings, so that the present magnification of figures 1–9 is approximately 600 diameters.

FIG. 1. Mature embryo sac. a = remnants of antipodals. *Petunia nyctaginiflora* Juss. Pop. 14. Slide made by Priscilla Presbrey.

FIG. 2. Embryo sac showing tip of pollen tube at base of egg, the polar nuclei not fully united and one antipodal nucleus still intact. d = nucleus of synergid. c = chromidia or other deeply staining material in the pollen tube. *s. n.* = sperm nuclei. Pop. 8, 85 hours after pollination.

FIG. 3. Embryo sac showing tip of pollen tube at base of egg and endosperm nucleus fully established. No trace of polars to be found. Pop. 14, 80 hours after pollination. Slide made by Hannah Adams.

FIG. 4. Micropylar end of embryo sac. Both sperm nuclei still within the pollen tube and primary endosperm nucleus in telophase of division. Pop. 14, 90 hours after pollination. Slide made by Priscilla Presbrey.

FIG. 5. Embryo sac after first division of endosperm. The micropylar endosperm cell smaller than the basal. The two sperm nuclei still within the pollen tube. Pop. 14. Slide made by Gertrude McDiarmid.

FIG. 6. Embryo sac with two-celled endosperm, showing the lower sperm nucleus just escaped from the pollen tube. Pop. 6, 96 hours after pollination.

FIG. 7. Embryo sac with two-celled endosperm. One sperm nucleus still within the tube, the other in contact with the nucleus of the micropylar endosperm cell. d = nucleus of synergid. *e. n.* = egg nucleus. Pop. 8, 96 hours after pollination.

FIG. 8. Embryo sac with two-celled endosperm, the basal cell in division. The lower sperm nucleus has just come in contact with the nucleus of the micropylar endosperm cell. *d* = nucleus of synergid. F_1 of Pop. 8 × Pop. 6, 100 hours after pollination.

FIG. 9. An embryo sac with three endosperm cells. The two sperm nuclei still within the tube. *b* = disintegrating nucellar tissue. F_1 of Pop. 14 × Pop. 8, 112 hours after pollination. Material put up by Gertrude Seelye.

Plate 36

FIG. 10. Embryo sac with three endosperm cells, the basal one in division. Sperm nuclei still in tube, the lower one about to escape. × 600. *e. n.* = egg nucleus. 124 hours after pollination.

FIG. 11. Embryo sac with three endosperm cells derived from the primary, basal, endosperm cell. The primary, micropylar, endosperm cell has not divided but its nucleus and the lower sperm nucleus have united to form the one large 'fusion-nucleus.' The second sperm nucleus still within the tube. × 600. *b* = disintegrating nucellar tissue. Pop. 8, 120 hours after pollination. Slide made by Louise Hall.

FIG. 12. A typical embryo sac at the time when the 'fusion-nucleus' of the primary, micropylar, endosperm cell divides. One sperm still within the pollen tube. × 600. F_1 of Pop. 14 × Pop. 8, 120 hours after pollination.

FIG. 13. The upper portion of an embryo sac after perpendicular or longitudinal walls have been formed in the primary, micropylar, endosperm cell and in the uppermost cell derived from the basal, primary, endosperm cell. × 600. Pop. 14, 120 hours after pollination. Slide made by Phyllis Albert.

FIG. 14. Cross section of an embryo sac after each of the four original endosperm cells have been divided into quadrants. × 280. F_1 of Pop. 14 × Pop. 8, 144 hours after pollination. Slide made by Dorothy Hammond.

FIG. 15. A late prophase in the division of the lower cell resulting from the division of the primary, basal, endosperm cell. Its position is similar to that of the division figure shown in figure 10. 14 chromosomes are shown, in two groups of 7 each. × 2000. Pop. 14, 96 hours after pollination. Slide made by Rachel Schreiner.

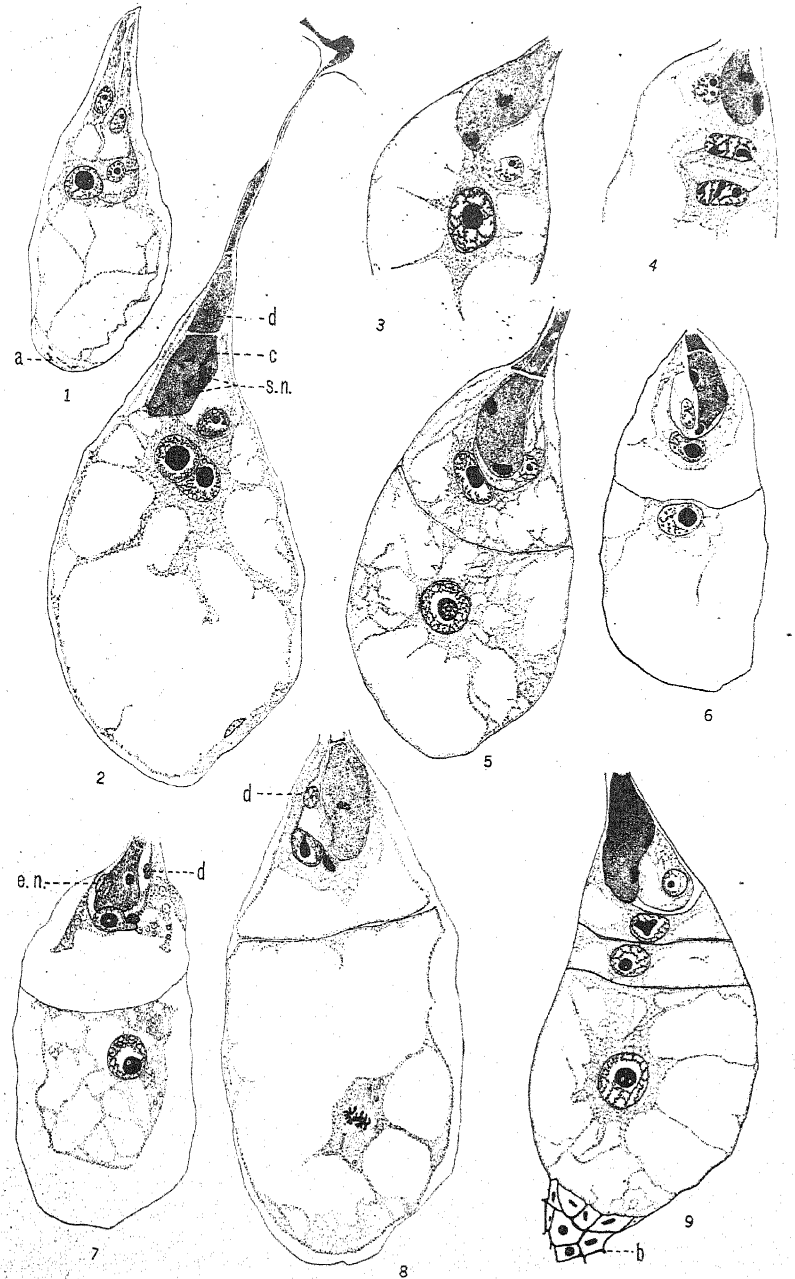
FIG. 16. Late prophase in the division of the 'fusion-nucleus' in the primary, micropylar, endosperm cell. Position of the mitotic figure is similar to the earlier stage shown in figure 12. 21 chromosomes are present. × 2000. F_1 of Pop. 14 × Pop. 8, 120 hours after pollination. Slide made by Marion Hunsicker.

FIG. 17, *a–e*. Various aspects of the sperm nucleus when in the tip of the pollen tube after its entrance into the embryo sac. × 2000. 90–96 hours after pollination. 17*a* = F_1 of Pop. 14 × Pop. 8. Slide made by Priscilla Presbrey. 17*b–e* = Pop. 5. Slide made by Dorothy Butler.

FIG. 18. A coiled sperm nucleus in contact with the nucleus of the primary, micropylar, endosperm cell. × 2000. Pop. 5, 96 hours after pollination. Slide made by Dorothy Butler.

FIG. 19. A later stage in the union of the sperm nucleus with the nucleus of the uppermost endosperm cell. × 1000. Pop. 6, 144 hours after pollination.

FIG. 20. The 'fusion-nucleus' in the primary, micropylar, endosperm cell. × 1000. Slide made by Miriam Schmaltz.



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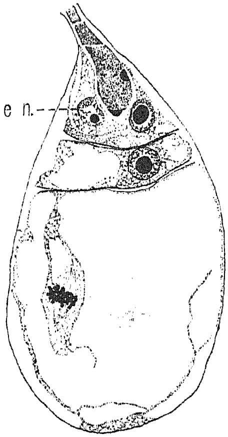

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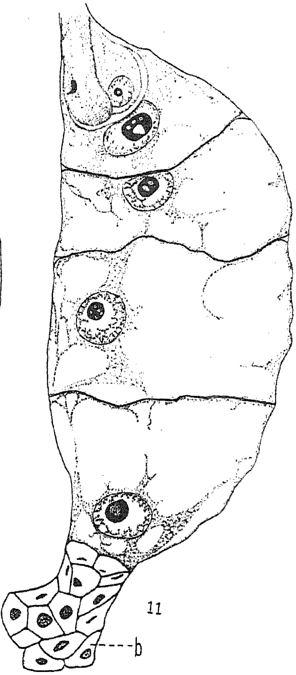

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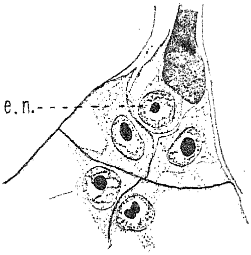

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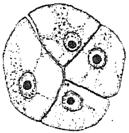

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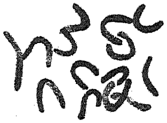

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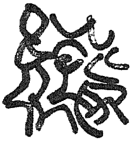

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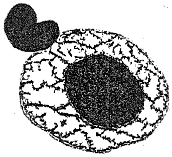

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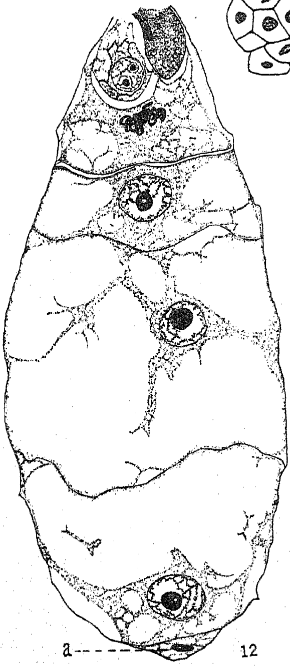

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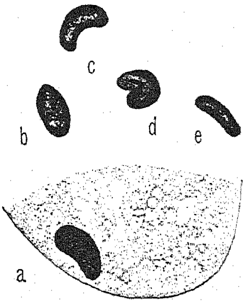

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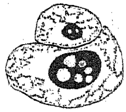

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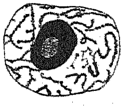

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ENDOSPERM FORMATION IN PETUNIA

INDEX TO AMERICAN BOTANICAL LITERATURE
1926–1927

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Albert, W. B. Studies on the growth of alfalfa and some perennial grasses. Jour. Am. Soc. Agron. **19:** 624–654. *f. 1–3.* Jl 1927.

Alberts, H. W. Relation of endosperm character in corn to absorption of hygroscopic moisture. Jour. Am. Soc. Agron. **19:** 590–595. *f. 1.* Jl 1927.

Alexander, E. J. *Melia azedarach.* Addisonia **12:** 17–18. *pl. 393.* 30 Je 1927.
Native of China and Persia.

Allan, J. A., & Rutherford, R. L. Paskapoo fossil plant localities of Alberta. Proc. Trans. Roy. Soc. Canada III. **20**^{4}**:** 183–186. *map.* 1926.

Allen, R. F. A cytological study of orange leaf rust, *Puccinia triticina* physiologic form 11, on Malakoff wheat. Jour. Agr. Res. **34:** 697–714. *pl. 1–7.* 15 Ap 1927.

Alway, F. J., & Nesoon, G. H. Inoculation of alfalfa on lime-deficient sandy soils. Minnesota Agr. Exp. Sta. Tech. Bull. 46: 1–62. *f. 1–10.* Mr 1927.

Ames, J. W., & Gerdel, R. W. The seedling plant method of determining soil nutrient deficiency. Soil Sci. **23:** 455–466. *f. 1.* Je 1927.

Andersen, A. M. Development of the female gametophyte and caryopsis of *Poa pratensis* and *Poa compressa.* Jour. Agr. Res. **34:** 1001–1018. *f. 1–3 + pl. 1–9.* 1 Je 1927.

Anderson, R. J., & Nabenhauer, F. P. Anthocyans appearing in the pigment of Isabella grapes. New York (Geneva) Agr. Exp. Sta. Tech. Bull. 123: 1–13. D 1926.

Andrews, F. M. Devices for sowing and growing spores. Plant Physiol. **2**: 216–219. *f. 2*. Ap 1927.

Annand, P. N. Tumors in kale. Science II. **65**: 553–554. 3 Je 1927.

Appleman, C. O., Loomis, W. E., Phillips, T. G., Tottingham, W. E., & Willaman, J. J. The determination of nitrogen in relatively simple compounds. Plant Physiol. **2**: 205–211. Ap 1927.

Appleman, C. O., Loomis, W. E., Phillips, T. G., Tottingham, W. E., & Willaman, J. J. The determination of soluble carbohydrates. Plant Physiol. **2**: 195–204. Ap 1927.

Baker, H. R. *Buxbaumia aphylla* near Newark, Delaware. Bryologist **30**: 45. "My" 15 S 1927.

Baldwin, I. L., & Fred, E. B. The fermentation characters of the root nodule bacteria of the Leguminosae. Soil Sci. **24**: 217–230. S 1927.

Balyeat, R. M. Factors which determine the pollen content of the air. Jour. Lab. & Clin. Med. **12**: 1151–1156. S 1927.

Barnes, W. C. George Bishop Sudworth. Science II. **66**: 6–8. 1 Jl 1927.

Born 31 Au 1864. Died 10 My 1927.

Barrel, G. H. Notes on *Amazonia*. Tropical Woods 11: 1–4. 1 S 1927.

Bartram, E. B. Some Arizona mosses not previously reported from the United States. Bryologist **30**: 45–50. "My" 15 S 1927.

Berry, E. W. Cycads in the Shinarump conglomerate of southern Utah. Jour. Washington Acad. Sci. **17**: 303–307. 4 Je 1927.

Berry, E. W. Devonian floras. Am. Jour. Sci. V. **14**: 109–120. *f. 1–8*. Au 1927.

Berry, E. W. On fossil plants from the Paskapoo Formation of Alberta. Proc. Trans. Roy. Soc. Canada III. **20**^{4}: 189–209. 1926.

Binstead, C. H. Mosses of the French Riviera. Bryologist **30**: 26–27. "Mr" 15 Jl 1927.

Blake, S. F. A new *Hymenothrix* from Arizona. Proc. Biol. Soc. Washington **40**: 49–50. 30 Je 1927.
H. Loomisii.

Blake, S. F. New South American species of *Liabum.* Jour. Washington Acad. Sci. **17**: 288–303. 4 Je 1927.

Blake, S. F. Two new species of *Securidaca* from South America. Proc. Biol. Soc. Washington **40**: 51–53. 30 Je 1927.
S. cayennensis and *S. leiocarpa.*

Blakeslee, A. F. A paradise for plant lovers. The biological station at Alto da Serra, Brazil. Sci. Mo. **25**: 5–18. *illust.* Jl 1927.

Blakeslee, A. F., Morrison, G., & Avery, A. G. Mutations in a haploid *Datura.* Jour. Hered. **18**: 193–199. *f. 1–3.* "My" 23 Jl 1927.

Boyce, J. S. *Lophodermium infectans* Mayr a synonym of *Hypoderma robustum* Tubeuf. Mycologia **19**: 284–285. *f. 1.* 1 S 1927.

Boynton, K. R. *Arthropodium cirrhatum.* Addisonia **12**: 19. *pl. 394.* 30 Je 1927.
Native of New Zealand.

Boynton, K. R., & Becker, H. W. *Zantedeschia aethiopica.* Addisonia **12**: 29–30. *pl. 399.* 30 Je 1927.
Native of South Africa.

Brink, R. A. The occurrence of semi-sterility in maize. Jour. Hered. **18**: 266–270. *f. 13, 14.* "Je" 10 S 1927.

Brink, R. A., & Burnham, C. R. Differential action of the sugary gene in maize on two alternative classes of male gametophytes. Genetics **12**: 348–378. *f. 1–6.* "Jl" 9 Au 1927.

Brinley, F. J. Penetration of hydrogen cyanide into living cells. Protoplasma **2**: 385–391. *f. 1–3.* Au 1927.

Britton, N. L. *Angelonia salicariaefolia.* Addisonia **12:** 23–24. *pl. 396.* 30 Je 1927.
Native of West Indies and northern South America.

Britton, N. L. *Sabinea punicea.* Addisonia **12:** 21. *pl. 395.* 30 Je 1927.
Native of Porto Rico.

Brooks, M. M. Studies on the permeability of living cells. VIII. The effect of chlorides upon the penetration of dahlia into *Nitella.* Protoplasma **2:** 420–427. *f. 1–3.* Au 1927.

Brown, N. E. *Lanugia,* a new genus of rubber-yielding trees. Torreya **27:** 51–53. 25 Je 1927.

Bryan, M. K. The flagella of *Bacillus amylovorus.* Phytopathology **17:** 405–406. *pl. 18.* 15 Je 1927.

Buchholz, J. T., & Blakeslee, A. F. Pollen-tube growth at various temperatures. Am. Jour. Bot. **14:** 358–369. *f. 1–3.* 28 Jl 1927.

Burlage, H. M., & Lynn, E. V. Examination of *Asarum caudatum.* Jour. Am. Pharm. Assoc. **16:** 407–411. My 1927.

Buswell, W. M. The cannon-ball tree. Am. Bot. **33:** 97–100. *illust.* Jl 1927.

Campbell, D. H. The embryology of *Equisetum debile* Roxb. Proc. Nat. Acad. Sci. **13:** 554–555. 15 Jl 1927.

Carver, W. A. A genetic study of certain chlorophyll deficiencies in maize. Genetics **12:** 415–440. *f. 1.* "S" 25 Au 1927.

Chaney, R. W., & Mason, H. L. Fossil plants. Science II. **66:** 156–157. 12 Au 1927.
In ashphalt pit at Carpinteria, California.

Chase, A. The case of the grass genus *Dilepyrum.* Rhodora **29:** 158–160. 1 Au 1927.

Cheney, R. H. Coffee: The plant and the beverage. Jour. N. Y. Bot. Gard. **28:** 190–193. Au 1927.

Clark, R. H., & Winter, A. G. The alkaloidal content of British Columbian grown *Hydrastis canadensis* and *Atropa Belladonna.* Proc. Trans. Roy. Soc. Canada III. **20**^{3}**:** 307–312. 1926.

Clarke, S. E. Self-fertilization in Timothy. Sci. Agr. **7**: 409–439. *f. 1–4.* Jl 1927.

Clayton, E. E. Effect of early spray and dust applications on later incidence of cucumber wilt and mosaic diseases. Phytopathology **17**: 473–481. 15 Jl 1927.

Clute, W. N. The meaning of plant names—XXXI. Verbenaceae. Am. Bot. **33**: 111–114. Jl 1927.

Cockerell, T. D. A. The flora of Yezo (Japan). Torreya **27**: 45–50. 25 Je 1927.

Cockerell, T. D. A. A supposed fossil catmint. Torreya **27**: 54. 25 Je 1927.
Nepeta (?) *pseudaeluri* n. sp.

Cole, J. L., Lindstrom, E. W., & Woodworth, C. M. Selection for quality of oil in soy beans. Jour. Agr. Res. **35**: 75–95. *f. 1–3.* 1 Jl 1927.

Colley, R. H., & Weston, W. H., Jr. George Richard Lyman, 1871–1926. Phytopathology **17**: 355–361. *port.* 15 Je 1927.
Born 1 D 1871. Died 7 Je 1926.

Collingwood, G. H. Pines of progress. Am. For. & For. Life **33**: 525–529. *illust.* S 1927.

Conner, A. B., & Karper, R. E. Hybrid vigor in sorghum. Texas Agr. Exp. Sta. Bull. 359: 1–23. *f. 1–6.* My 1927.

Cooper, C. S. Mosses in the Highlands of Scotland. Bryologist **30**: 51–53. "My" 15 S 1927.

Cooper, D. C. Anatomy and development of tomato flower. Bot. Gaz. **83**: 399–411. *f. 1–7 + pl. 11, 12.* 22 Je 1927.

Copeland, E. B. Nomenclature of the Abaca plant. Philipp. Jour. Sci. **33**: 141–153. Je 1927.

Corne, F. E. A Caribbean cruise and some Jamaican wayside ferns—III. Am. Fern Jour. **17**: 86–90. S 1927.

Davison, F. R., & Willaman, J. J. Biochemistry of plant diseases. IX. Pectic enzymes. Bot. Gaz. **83**: 329–361. *f. 1–5.* 22 Je 1927.

Dearness, J. Fleshy fungi. Mycologia **19**: 228–229. 1 Jl 1927.

Denny, F. E. The effect of small amounts of chemicals in increasing the life activities of plants. Proc. Nat. Acad. Sci. **13**: 555–561. 15 Jl 1927.

Denny, F. E., & Youden, W. J. Acidification of unbuffered salt solutions by plant tissue, in relation to the question of tissue isoelectric points. Am. Jour. Bot. **14**: 395–414. *f. 1–5.* 28 Jl 1927.

Denslow, H. M. Native orchids in and near New York. Torreya **27**: 61–63. "Jl–Au" 17 S 1927.

Dickson, B. T. Two epimycetous fungi. Proc. Trans. Roy. Soc. Canada III. **20**^{5}: 113–116. *pl. 1.* 1926.

Acontium ustilaginicola and *Hypomyces inaequalis.*

Dixon, H. N. Regeneration of *Tortula muralis.* Bryologist **30**: 28–29. "Mr" 15 Jl 1927.

Dobbie, H. B. The Oropi Bush, Tauranga, New Zealand. Am. Fern Jour. **17**: 98–101. *illust.* S 1927.

Drechsler, C. An emendation of the description of *Aphiobolus heterostrophus.* Phytopathology **17**: 414. 15 Je 1927.

Durrell, L. W., & Glover, G. H. Poisonous plants of Colorado. Colorado Agr. Exp. Sta. Bull. 316: 1–28. *illust.* Mr 1927.

Durrell, L. W., & Lute, A. M. The puncture vine—a serious weed in Colorado. Colorado Agr. Exp. Sta. Ext. Serv. Circ. 46: 1–4. *illust.* O 1926.

Dye, M., Medlock, O. C., & Crist, J. W. The association of vitamin A with greenness in plant tissue. I. The relative vitamin A content of head and leaf lettuce. Jour. Biol. Chem. **74**: 95–106. *f. 1–6.* Jl 1927.

East, E. M. The inheritance of heterostyly in *Lythrum Salicaria.* Genetics **12**: 393–414. "S" 25 Au 1927.

Eastwood, A. New species of *Ceanothus.* Proc. California Acad. Sci. IV. **16**: 361–363. Ap 1927.

C. cyaneus, C. insularis, and *C. utahensis.*

Eddy, C. O. The place of the native persimmon in nature, in relation to other plant communities, and to certain economic insects. Ohio Jour. Sci. **27**: 187–199. *f. 1–3.* 25 Jl 1927.

Ekman, E. Notes on some Greenland *Antennariae.* Svensk Bot. Tidsk. **21**^{1}: 49–57. *pl. 1.* 1927.

Emerson, G. W., & Lloyd, F. E. A starch test in photosynthesis experiments. Science II. **65**: 598–599. 17 Je 1927.

Evans, A. T. Delayed dormancy as a probable cause of uneven stands in planted potatoes. Am. Jour. Bot. **14**: 284–286. *pl. 31.* "My" 2 Je 1927.

Evans, A. W. A further study of the American species of *Symphyogna.* Trans. Conn. Acad. Arts & Sci. **28**: 295–354. *f. 1–12 + pl. 1.* Au 1927.

Evans, A. W. Notes on Connecticut lichens. Rhodora **29**: 97–105. 22 Je 1927.

Fairchild, D. The tomato terraces of Bañalbufar. An agricultural monopoly built on a single variety of tomato. Jour. Hered. **18**: 245–251. *f. 2–7.* "Je" 10 S 1927.

Farwell, O. A. Contributions to the botany of Michigan. XIII. Notes on grasses of Michigan and some others. Am. Midl. Nat. **10**: 305–316. Jl 1927.

Fawcett, G. L. The curly top of sugar beet in the Argentine. Phytopathology **17**: 407–408. 15 Je 1927.

Fernald, M. L. The American *Cardamine parviflora.* Rhodora **29**: 191–192. 12 S 1927.

Fernald, M. L. Three new plants from the lower St. Lawrence. Rhodora **29**: 141–144. 1 Au 1927.

Erysimum coarctatum, Solidago anticostensis and *S. Victorinii.*

Ferris, R. S. Preliminary report on the flora of the Tres Marias Islands. Contr. Dudley Herb. Stanford Univ. **1**: 63–88. *pl. 1–4.* 21 My 1927.

Several species described as new.

Fink, B. New species of lichens from Porto Rico. I. Graphidaceae. Mycologia **19**: 206–221. 1 Jl 1927.

In *Opegrapha, Melaspilea, Graphis, Phaeographis, Graphina,* and *Phaeographina.*

Fiske, J. G. Poison ivy. New Jersey Agr. Exp. Sta. Circ. 206: 1–8. *f. 1–3.* Jl 1927.

Fitzpatrick, H. M. Curtis Gates Lloyd. Mycologia **19:** 153–159. *pl. 12.* 1 Jl 1927.
Born 17 Jl 1859. Died 11 N 1926.

Fulling, E. H. Wisteria. Jour. N. Y. Bot. Gard. **28:** 194–197. *f. 2.* Au 1927.

Garner, W. W., & Allard, H. A. Effect of short alternating periods of light and darkness on plant growth. Science II. **66:** 40–42. 8 Jl 1927.

Gates, F. C. Establishment of plant associations. Ecology **8:** 339–340. Jl 1927.

Gates, R. R. Mutations: Their nature and evolutionary significance. Am. Nat. **61:** 457–465. S–O 1927.

Gericke, W. F. Why applications of nitrogen to land may cause either increase or decrease in the protein content of wheat. Jour. Agr. Res. **35:** 133–139. 15 Jl 1927.

Gerritson, W. A moss walk early in March. Bryologist **30:** 55–56. "My" 15 S 1927.

Gibbs, R. D. The action of ultra-violet light on *Spirogyra.* Proc. Trans. Roy. Soc. Canada III. **20**^{5}: 419–429. *pl. 1.* 1926.

Gilbert, B. E., McLean, F. T., & Adams, W. L. The current mineral nutrient content of the plant solution as an index of metabolic limiting conditions. Plant Physiol. **2:** 139–151. *f. 1–7.* Ap 1927.

Gilbert, F. A. Notes on Myxomycetes from eastern Massachusetts. Rhodora **29:** 165–173. 12 S 1927.

Gilbert, F. A. On the occurrence of biflagellate swarm cells in certain Myxomycetes. Mycologia **19:** 277–283. *f. 1, 2.* 1 S 1927.

Gilman, J. C., & Abbott, E. V. A summary of the soil fungi. Iowa Coll. Jour. Sci. **1:** 225–343. *f. 1–83.* Ap 1927.

Gleason, H. A. Further views on the succession-concept. Ecology **8:** 299–326. Jl 1927.

Godfrey, M. J. Natural orchid hybrids. Genetica **9:** 19–38. *f. 1–6 + pl. 1.* 1927.

Graham, V. O. Seasonal occurrence of the larger fungi. Trans. Illinois Acad. Sci. **19:** 182–186. 1926.

Gratz, L. O., & Bonde. R. Infection of potato tubers by *Alternaria Solani* in relation to storage conditions. Florida Agr. Exp. Sta. Bull. 187: 167–181. *f. 109–117.* Je 1927.

Graves, E. W. Distribution of the Hart's Tongue. Am. Fern. Jour. **17:** 95–97. S 1927.

Gray, F. W. An explanation of the occurrence of certain new Cladonias. Bryologist **30:** 23–25. "Mr" 15 Jl 1927.

Greenwood, H. E. Great moments in little lives. Bryologist **30:** 43–44. "My" 15 S 1927.

Discovery of rare plants.

Gress, E. M. Enjoy but do not destroy wild flowers. Pennsylvania Dept. Agr. Bull. 9^{13}: 1–24. *illust.* Jl 1927.

Griffiths, D. Naturalizing bulbous plants. Am. For. & For. Life **33:** 550–555. *illust.* S 1927.

Groh, H. A Prince Edward Island weed survey. Sci. Agr. **7:** 388–395. Je 1927.

Grout, A. J. Collecting mosses along the Florida west coast. Bryologist **30:** 29–30. "Mr" 15 Jl 1927.

Gundersen, A. The Frankeniaceae as a link in the classification of dicotyledons. Torreya **27:** 65–71. "Jl–Au" 17 S 1927.

Güssow, H. T., & Conners, I. L. Studies in cereal diseases. Smut diseases of cultivated plants, their cause and control. Canada Dept. Agr. Bull. 81: 1–79. *f. 1–20.* 1927.

Gustafson, F. G. Growth studies on fruits; an explanation of the shape of the growth curve. Plant Physiol. **2:** 153–161. *f. 1–3.* Ap 1927.

Hall, R. P., & Powell, W. N. A note on the morphology and systematic position of the flagellate *Peranema trichophorum.* Trans. Am. Micros. Soc. **46:** 155–165. *pl. 1.* Jl 1927.

Hansen, A. A. Nineteen noxious weeds of Indiana. Indiana Agr. Exp. Sta. Circ. 106: 1–32. *illust.* 1 Mr 1927.

Harris, J. A. The Lunell Herbarium. Science II. **66:** 110. 21 Jl 1927.

Harris, J. A. Physiological differences in varieties; a graphical representation of chemical differences in the tissue fluids of Egyptian and Upland cotton. Jour. Hered. **18:** 277–279. *f. 15.* "Je" 10 S 1927.

Harvey, R. P. Ionization and adsorption isoelectric points. Plant Physiol. **2:** 220. Ap 1927.

Haskin, L. L. The versatile cat-tail. Nat. Mag. **10:** 178–180. *illust.* S 1927.

Haynes, C. C. Some Virginian Hepaticae identified by Caroline Coventry Haynes. Bryologist **30:** 39–43. *pl. 3.* "My" 15 S 1927.

Heilbrunn, L. V. The viscosity of protoplasm. Quar. Rev. Biol. **2:** 230–248. Je 1927.

Heimlich, L. F. The development and anatomy of the staminate flower on the cucumber. Am. Jour. Bot. **14:** 227–237. *f. 1 + pl. 24–26.* "My" 2 Je 1927.

Helwig, B. Convolvulaceae austro-americanae novae. II. Notizbl. Bot. Gart. Berlin **9:** 102–108. 10 Jl 1927.

Hesler, L. R. The perfect stage of *Hendersonia Mali.* Mycologia **19:** 222–227. 1 S 1927.
Pleospora Mali described as new.

Higgins, B. B. Physiology and parasitism of *Sclerotium Rolfsii* Sacc. Phytopathology **17:** 417–448. *f. 1–8.* 15 Jl 1927.

Hitchcock, A. S. New species of grasses from Central America. Proc. Biol. Soc. Washington **40:** 79–88. 30 Je 1927.

Hitchcock, A. S. The validity of the grass genus *Digitaria.* Rhodora **29:** 114–116. 22 Je 1927.

Hockey, J. F. Apple scab. Canada Dept. Agr. Pamphlet n. s. 82: 1–7. *f. 1–3.* 1927.

Hodgson, A. H. The whimsical root habits of western hemlock. Am. For. & For. Life **33**: 541–543. *illust.* S 1927.

Hofmann, F. W. Some attempts to modify the germ plasm of *Phaseolus vulgaris*. Genetics **12**: 284–294. *f. 1–5.* "My" 11 Jl 1927.

Hollick, A. *Quercus serrata.* Addisonia **12**: 25. *pl. 397.* 30 Je 1927.
Native of eastern and southern Asia.

Hollick, A. Some geological features of the New York Botanical Garden. Jour. N. Y. Bot. Gard. **28**: 197–200. Au 1927.

Holzinger, J. M. The distribution of *Grimmia Dupreti* Theriot. Bryologist **30**: 25. "Mr" 15 Jl 1927.

Holzinger, J. M. A note on *Conostomum tetragonum* (Dicks.) Lindb. (*C. boreale* Sw.). Bryologist **30**: 27. "Mr" 15 Jl 1927.

Howlett, F. S. Apple pollination studies in Ohio. Ohio Agr. Exp. Sta. Bull. 404: 1-84. *f. 1–13.* Ap 1927.

Hunt, W. R. Miscellaneous collections of North American rusts. Mycologia **19**: 286–288. 1 S 1927.

Hurt, R. H., & Schneiderhan, F. J. New methods of bitter rot control. Virginia Agr. Exp. Sta. Bull. 254: 1–22. *f. 1–6.* F 1927.

Imai, Y. A genetic analysis of white-margined flowers in the Japanese morning-glory. Genetics **12**: 199–241. "My" 11 Jl 1927.

Imai, Y., & Kanna, B. On the variability of a white-eared form in *Amarantus paniculatus*. Genetics **12**: 242–252. *f. 1.* "My" 11 Jl 1927.

Irwin, M. On the nature of the dye penetrating the vacuole of *Valonia* from solutions of methylene blue. Jour. Gen. Physiol. **10**: 927–947. *f. 1–4.* 20 Jl 1927.

Johnson, E. S. An apparatus for controlling the flow of nutrient solutions in plant cultures. Plant Physiol. **2**: 213–215. *f. 1.* Ap 1927.

Jones, D. B., & Csonka, F. A. Studies on glutelins. II. The glutelin of rice (*Oryza sativa*). Jour. Biol. Chem. **74:** 427–431. S 1927.

Jones, D. B., & Gersdorff, E. F. The globulins of rice, *Oryza sativa.* Jour. Biol. Chem. **74:** 415–426. S 1927.

Jones, J. W. Inheritance of awnedness in rice. Jour. Am. Soc. Agron. **19:** 830–839. *f. 1.* S 1927.

Jorgenson, L., & Brewbaker, H. E. A comparison of selfed lines of corn and first generation crosses between them. Jour. Am. Soc. Agron. **19:** 819–830. S 1927.

Kanouse, B. B. A monographic study of special groups of the water molds. I. Blastocladiaceae. II. Leptomitaceae and Pythiomorphaceae. Am. Jour. Bot. **14:** 287–306; 335–357. *pl. 32–34, 48.* "Je" 7 Jl, 28 Jl 1927.

Order Leptomitales, genus *Mindeniella,* and several species described as new.

Kauffman, C. H. Why the differences in published spore-sizes? Mycologia **19:** 289–291. 1 S 1927.

Kaufmann, B. P. The value of the smear method for plant cytology. Stain Tech. **2:** 88–90. Jl 1927.

Keen, B. A. Relation of soils to plant growth. Jour. N. Y. Bot. Gard. **28:** 231–232. S 1927.

Kempton, J. H. Age of pollen and other factors affecting Mendelian ratios in maize. Jour. Agr. Res. **35:** 39–74. *f. 1, 2.* 1 Jl 1927.

Kennedy, P. B., & Frederick, A. Old world weed introductions. Jour. Am. Soc. Agron. **19:** 569–573. *pl. 1.* Jl 1927.

Keck, D. D. A revision of the genus *Orthocarpus.* Proc. California Acad. Sci. IV. **16:** 517–571. Je 1927.

Kenoyer, L. A. A study of Raunkiaer's law of frequence. Ecology **8:** 341–349. Jl 1927.

Kern, F. D., & Chardon, C. E. Notes on some rusts of Colombia. Mycologia **19:** 268–276. 1 S 1927.

Kienholz, R. An ecological-anatomical study of beach vegetation in the Philippines. Proc. Am. Phil. Soc. **65** (suppl.): 58–100. *pl. 1–6.* 1926.

Killip, E. P. New species of *Cordia* and *Tournefortia* from northwestern South America. Jour. Washington Acad. Sci. **17**: 327–335. 19 Jl 1927.

Killip, E. P. Report of the Killip-Smith Botanical Expedition to Colombia, 1926–1927. Jour. N. Y. Bot. Gard. **28**: 205–220. *f. 1–7.* S 1927.

Killough, D. T., & Hafner, V. E. Varieties of cotton for the Gulf coastal plains of Texas. Texas Agr. Exp. Sta. Bull. 354: 1–39. My 1927.

King, C. J., & Loomis, H. F. Factors influencing the severity of the crazy-top disorder of cotton. U. S. Dept. Agr. Bull. 1484: 1–20. *pl. 1–6.* Je 1927.

Kirk, L. E. Self-fertilization in relation to forage crop improvement. Sci. Agr. **8**: 1–40. *pl. 1–5.* S 1927.

Knowlton, F. H. Plants of the past; a popular account of fossil plants. 1–275. *f. 1–90.* Princeton, Univ. Press, 1927.

Koehler, B. Studies on the scutellum rot disease of corn. Phytopathology **17**: 449–471. *f. 1–6.* 15 Jl 1927.

Kotowski, F. Semipermeability of seed coverings and stimulation of seeds. Plant Physiol. **2**: 177–186. Ap 1927.

Krauss, F. G. Improvement of the pigeon pea. Jour. Hered. **18**: 227–232. *f. 15–19.* "My" 23 Jl 1927.

Larsen, J. A. Relation of leaf structure of conifers to light and moisture. Ecology **8**: 371–377. *pl. 5.* Jl 1927.

Latham, R. *Tipularia uniflora* on Montauk Point, Long Island. Torreya **27**: 51. 25 Je 1927.

Laughlin, B. R. A little fern garden in Ohio. Am. Fern. Jour. **17**: 102–104. S 1927.

Lee, S. Cytological study of *Stigonema mammilosum.* Bot. Gaz. **83**: 420–424. *pl. 13.* 22 Je 1927.

Leonian, L. H. The effect of different hosts upon the sporangia of some Phytophthoras. Phytopathology **17**: 483–490. *f. 1–5.* 15 Jl 1927.

Lesley, M. M. Mendel's letters to Carl Nägeli. Am. Nat. **61**: 370–378. Jl 1927.

Lesley, M. M., & Frost, H. B. Mendelian inheritance of chromosome shape in *Matthiola*. Genetics **12**: 449–460. *f. 1–4.* "Au" 25 S 1927.

Leukel, W. A. Deposition and utilization of reserve foods in alfalfa plants. Jour. Am. Soc. Agron. **19**: 596–623. Jl 1927.

Lewis, I. M., & Watson, E. A. Bacterial disease of *Bowlesia*. Phytopathology **17**: 507–512. 15 Jl 1927.
Phytomonas Bowlesii described as new.

Lind, J. The geographical distribution of some arctic micromycetes. K. Danske Videns. Selskab. Biol. Meddel. **6**^{5}: 1–45. 30 Je 1927.

Lind, J. Micromycetes from northwestern Greenland found on plants collected during the jubilee expedition 1920–1923. Meddel. Grønland **71**: 161–179. 1926.

Linford, M. B., & Sprague, R. Species of *Ascochyta* parasitic on the pea. Phytopathology **17**: 381–397. *f. 1, 2 + pl. 16–17.* 15 Je 1927.

Link, G. K. K., & Hull, K. L. Smoothness and roughness and spontaneous agglutination of *Bacterium Citri*, *Bacterium Medicaginis* var. *phaseolicola*, *Bacterium Phaseoli sojense*, and *Bacterium tumefaciens*. Bot. Gaz. **83**: 411–419. *f. 1–3.* 22 Je 1927.

Liu, H. The salt requirements of tobacco grown in sand cultures. Maryland Agr. Exp. Sta. Bull. 288: 132–153. *f. 1–3 + pl. 1–4.* N 1926.

Lloyd, F. E. Studies on *Spirogyra*. I. Additional studies on conjugation. II. Adhesions and geniculations. Proc. Trans. Roy. Soc. Canada III. **20**^{5}: 75–110. *2 pl.* 1926.

Lloyd, F. E., & Úlehla, V. The rôle of the wall in the living cell as studied by the auxographic method. I. The effect of concentration of the medium on the stipe tissues of *Postelia palmaeformis*, Rupr. Proc. Trans. Roy. Soc. Canada III. 20^5: 45–73. *f. 1–7.* 1926.

Lombard, L. H. Hibernation of three water plants. Am. Bot. **33**: 114–116. Jl 1927.

Lemna minor, *Ceratophyllum demersum* and *Utricularia cornuta.*

Lucas, F. A. Charles Sprague Sargent. Nat. Hist. **27**: 291. *port.* My–Je 1927.

Born 24 Ap 1841. Died 22 Mr 1927.

Lutz, B. The flora of the Serra da Bocaina. Proc. Am. Phil. Soc. **65** (suppl.): 27–43. 1926.

Lyon, C. J. The rôle of phosphate in plant respiration. Am. Jour. Bot. **14**: 274–283. "My" 2 Je 1927.

McAllister, F. The pyrenoids of *Anthoceros* and *Notothylas* with especial reference to their presence in spore mother cells. Am. Jour. Bot. **14**: 246–257. *pl. 27, 28.* "My" 2 Je 1927.

MacBride, J. F. Various spermatophytes. 1. The perennial South American Paroselas. 2. Further Peruvian Psoraleas. 3. An earlier name for *Muhlenbeckia.* 4. New Peruvian Malesherbias. 5. A defense of *Allocarya.* 6. Notes on *Cucumis*, *Palafoxia*, *Liatris.* Field Mus. Nat. Hist. Publ. 244: 99–124. 31 My 1927.

McCullagh, D. R. Preliminary note on the distribution of glucosides in western Canadian plants. Proc. Trans. Roy. Soc. Canada III. 20^5: 331–338. 1926.

McDonald, C. C. A study of seed development in three species of *Erigeron* with special reference to apogamy. Bull. Torrey Club **54**: 479–497. *pl. 32, 33.* "Je" 2 S 1927.

MacDougal, D. T., & Long, F. L. Characters of cells attaining great age. Am. Nat. **61**: 385–406. *f. 1–4.* S–O 1927.

MacDougal, D. T., & Moravek, V. The activities of a constructed colloidal cell. Protoplasma **2**: 161–188. *f. 1–10.* Je 1927.

McDougall, W. B., & Jacobs, M. C. Tree mycorhizas from the central Rocky Mountain region. Am. Jour. Bot. **14**: 258–266. *pl. 29.* "My" 2 Je 1927.

MacFarlane, J. M. The Philippine species of *Nepenthes.* Philippine Jour. Sci. **33**: 127–140. Je 1927.

McKinney, H. H. Factors affecting certain properties of a mosaic virus. Jour. Agr. Res. **35**: 1–12. 1 Jl 1927.

McKinney, H. H. Quantitative and purification methods in virus studies. Jour. Agr. Res. **35**: 13–38. *f. 1–3.* 1 Jl 1927.

McMurray, N. Some wild grasses. Am. Bot. **33**: 116–117. Jl 1927.

Maneval, W. E. Further germination tests with teliospores of rusts. Phytopathology **17**: 491–498. 15 Jl 1927.

Mangelsdorf, A. J., & East, E. M. Studies on the genetics of *Fragaria.* Genetics **12**: 307–339. *f. 1–7.* "Jl" 9 Au 1927.

Manning, W. H. Exotic trees for forest plantations. Am. For. & For. Life **33**: 535, 568. *illust.* S 1927.

Martin, G. W. Basidia and spores of the Nidulariaceae. Mycologia **19**: 239–247. *pl. 22, 23.* 1 S 1927.

Martin, G. W. Two unusual water molds belonging to the family Lagenidiaceae. Mycologia **19**: 188–190. *f. 1.* 1 Jl 1927.

Maxon, W. R. Exploring for ferns in the Blue Mountains of Jamaica. Smithsonian Misc. Coll. **78**: 100–111. *f. 110–118.* 1927.

Melburn, M. C., & Thompson, W. P. The cytology of a tetraploid wheat hybrid (*Triticum spelta* × *T. monococcum*). Am. Jour. Bot. **14**: 327–333. *f. 1, 2.* "Je" 7 Jl 1927.

Melhus, J. E., & Elmer, O. H. Raspberry diseases in Iowa. Iowa Agr. Exp. Sta. Circ. 105: 1–15. *f. 1–7.* Je 1927.

Mellanoff, I. S., & Schaeffer, H. J. A study of the resins of *Podophyllum peltatum* L. Am. Jour. Pharm. **99**: 323–330. Je 1927.

Mildbraed, J. Plantae Tessmannianae peruvianae V. Notizbl. Bot. Gart. Berlin 9: 124–128. 10 Jl 1927.

Moldenhauer, C. A unique cabbage hybrid. One plant of Brussels sprouts × cabbage cross exhibits unusual combination of characters. Jour. Hered. **18:** 257–259. *f.* 9. "Je" 10 S 1927.

Moore, B., & Taylor, N. Vegetation of Mount Desert Island, and its environment. Brooklyn Bot. Gard. Mem. **3:** 1–151. *f. 1–27* + *pl. 1.* 10 Je 1927.

Moore, S. Notes on Jamaica plants. Jour. Bot. **65:** 219–221. Au 1927.

Moore, S. V. Indian pipe or ghost flower. Am. Bot. **33:** 107–108. Jl 1927.

Mousley, H. Further notes on *Malaxis unifolia.* Orchid. Rev. **35:** 163–164. *illust.* Je 1927.

Muenscher, W. C. Spartina patens and other saline plants in the Genesee Valley of western New York. Rhodora **29:** 138–139. 18 Jl 1927.

Mulford, F. L. Street and roadside trees. Am. For. & For. Life **33:** 404–407, 430. *illust.* Jl 1927.

Murrill, W. A. The yellow-gilled *Russula.* Mycologia **19:** 229–230. 1 Jl 1927.

Neff, D. I., & White, O. E. Inheritance studies in *Pisum* VI. Multiple allelomorphism and the inheritance of green and yellow foliage and pod color. Am. Jour. Bot. **14:** 379–394. 28 Jl 1927.

Nelson, A. A new *Pentstemon* from Arizona. Am. Bot. **33:** 109–110. Jl 1927.
P. Clutei.

Nelson, R. Storage and transportational diseases of vegetables due to suboxidation. Michigan Agr. Exp. Sta. Tech. Bull. 81: 1–38. *pl. 1–8.* D 1926.

Nevins, B. I. The development of the macrogametophyte of *Furcraea andina.* Am. Jour. Bot. **14:** 370–378. *f. 1* + *pl. 49, 50.* 28 Jl 1927.

Newton, W. Metabolism of nitrogen compounds in dormant and nondormant potato tubers. Jour. Agr. Res. **35**: 141–146. *f. 1, 2.* 15 Jl 1927.

Nightingale, G. T., Robbins, W. R., & Schermerhorn, J. G. Freezing as a method of preserving plant tissue for the determination of nitrogenous fractions. New Jersey Agr. Exp. Sta. Bull. 448: 1–16. Mr 1927.

Noe, A. C. The fossil flora of Harrisburg, Illinois. Illinois Acad. Sci. Trans. **19**: 283–285. 1926.

Osterhout, G. E. Concerning some species of *Machaeranthera.* Torreya **27**: 63–65. "Jl–Au" 17 S 1927.

Overholts, L. O. A monograph of the genus *Pholiota* in the United States. Ann. Missouri Bot. Gard. **14**: 87–210. *f. 1–174 + pl. 8–24.* Ap 1927.

Owen, F. V. Inheritance studies in soybeans. I. Cotyledon color. Genetics **12**: 441–448. "S" 25 Au 1927.

Pack, D. A. Ring density of sugar beets as a character for selection. Am. Jour. Bot. **14**: 238–245. "My" 2 Je 1927.

Paine, F. S. Studies of the fungous flora of virgin soils. Mycologia **19**: 248–267. *pl. 24–26.* 1 S 1927.

Palmer, E. F., & Strong, W. J. A note on raspberry breeding. Sci. Agr. **7**: 387. Je 1927.

Palmer, E. J. Ferns of the Davis Mountains, western Texas. Am. Fern Jour. **17**: 77–85. S 1927.

Peacock, J. C., & Peacock, B. L.D. Further study of the tannin of *Heuchera americana* L. Jour. Am. Pharm. Assoc. **16**: 729–737. Au 1927.

Peattie, D. C. Botanizing on Mt. Mitchell. Am. Bot. **33**: 101–107. Jl 1927.

Peattie, D. C. Cargoes and harvests. 1–311. *f. 1–16.* N.Y., Appleton, 1926.

Peattie, D. C. Erwin F. Smith—a young man's impression. Sci. Mo. **25**: 84–86. Jl 1927.

Pennell, F. W. Through the Andes of western Colombia. Jour. N. Y. Bot. Gard. **28:** 186–189. Au 1927.

Piness, G., & McMinn, H. E. The rôle of the structural features of pollen grains in identifying the most important hay fever plants of California. Jour. Lab. & Clin. Med. **12:** 1164–1178. *f. 1–24.* S 1927.

Pittier, H. Manual de las plantas usuales de Venezuela. i–xx, 1–458. *pl. 1–43.* Caracas, 1926.

Pittier, H. Six new Convolvulaceae from Venezuela. Jour. Washington Acad. Sci. **17:** 284–288. 4 Je 1927.
In *Brewia, Aniseia, Merremia* and *Ipomoea.*

Powers, W. L. The effect of hydrogen-ion concentration on the growth of certain plants. Soil Sci. **24:** 1–4. *pl. 1, 2.* Jl 1927.

Pring, G. H. Collecting orchids in the Chiriqui, Panama. Missouri Bot. Gard. Bull. **15:** 73–87. *pl. 5–11.* My 1927.

Proebsting, E. L., & Barger, E. H. The precipitin reaction as a means of determining the congeniality of grafts. Science II. **65:** 573–574. 10 Je 1927.

Rankin, W. H. Mosaic of raspberries. New York (Geneva) Agr. Exp. Sta. Bull. 543: 1–60. *pl. 1–8.* Mr 1927.

Record, S. J. *Mimosa Schomburgkii* discovered in Honduras. Tropical Woods 11: 24–25. 1 S 1927.

Record, S. J. Trees of Gualán, Guatemala. Tropical Woods 11: 10–18. 1 S 1927.

Record, S. J. The wood of *Tetrapodenia glandifera* Gleason. Tropical Woods 11: 22–24. 1 S 1927.

Rendle, A. B. Charles Sprague Sargent. Jour. Bot. **65:** 151–152. My 1927.
Born 24 Ap 1841. Died 22 Mr 1927.

Richey, F. D. The convergent improvement of selfed lines of corn. Am. Nat. **61:** 430–449. *f. 1.* S–O 1927.

Ricker, P. L. Friends in need among our wild flowers. Nat. Mag. **10:** 171–174. *6 col. pl.* S 1927.

Ricker, P. L. A wild flower paradise. Nat. Mag. **10:** 35–39. *6 col. pl.* Jl 1927.

Ripperton, J. C. Carbohydrate metabolism and its relation to growth in the edible canna. Hawaii Agr. Exp. Sta. Bull. 56: 1–35. 1927.

Robbins, C. A. The identity of *Cladonia Beaumontii.* Rhodora **29:** 133–138. *pl. 157.* 18 Jl 1927.

Roberts, J. W., & Dunegan, J. C. Critical remarks on certain species of *Sclerotinia* and *Monilia* associated with diseases of fruits. Mycologia **19:** 195–205. *pl. 15.* 1 Jl 1927.

Robinson, C. H. A semi-double wild rose new to botany. Nat. Mag. **10:** 62. *illust.* Jl 1927.
Captain Robinson wild rose.

Rosa, J. T. Chemical changes accompanying the western yellow blight of tomato. Plant Physiol. **2:** 163–169. Ap 1927.

Rose, J. N. *Dudleya albiflora.* Addisonia **12:** 31. *pl. 400.* 30 Je 1927.

Rose, J. N. Some Mimosaceae from Hispaniola. Jour. Washington Acad. Sci. **17:** 254–259. 19 My 1927.
Pithecolobium Abbottii and *Mimosa Leonardii* described as new.

Rosen, H. R. Erwin F. Smith—friend of youth. Mycologia **19:** 292–293. 1 S 1927.

Rosen, H. R. A pinkcolored form of *Polyporus sulphureus* and its probable relationship to root-rot of oaks. Mycologia **19:** 191–194. *pl. 16, 17.* 1 Jl 1927.

Rydberg, P. A. (Carduales) Carduaceae. Liabeae, Neurolaeneae, Senecioneae (pars). North Am. Flora **34:** 289–360. 22 Je 1927.

Rydberg, P. A. Two native bigeneric hybrids. Jour. N. Y. Bot. Gard. **28:** 227–228. *f. a, b.* S 1927.
Sorbus americana × *Aronia atropurpurea; Sorbus occidentalis* × *Amelanchier* sp.

Sand, A. W. W. A study of *Pogoniris* varieties. Cornell Agr. Exp. Sta. Memoir 100: 1–159. *f. 1–52.* Jl 1927.

Scarth, G. W. Stomatal movement; its regulation and regulatory rôle; a review. Protoplasma **2**: 498–511. Au 1927.

Scarth, G. W. The structural organization of plant protoplasm in the light of micrurgy. Protoplasma **2**: 189–205. *pl. 3.* Je 1927.

Scarth, G. W., & Lloyd, F. E. The rôle of kinoplasm in the genesis of vacuoles. Science II. **65**: 599–600. 17 Je 1927.
In *Spirogyra.*

Schaffner, J. H. Observations on the grasslands of the central United States. Ohio Univ. Stud. 178: 1–56. *f. 1–12.* 1926.

Schaffner, J. H. Sex and sex-determination in the light of observations and experiments on dioecious plants. Am. Nat. **61**: 319–332. *f. 1.* Jl 1927.

Schultz, E. S. Nuclear division and spore formation in the ascus of *Peziza domiciliana.* Am. Jour. Bot. **14**: 307–322. *pl. 35–39.* "Je" 7 Jl 1927.

Seaver, F. J. Botanizing in the mountains of Colorado. Jour. N. Y. Bot. Gard. **28**: 229–231. S 1927.

Serviss, G. P. The edelweiss. Nat. Mag. **10**: 25. *illust.* Jl 1927.

Shantz, H. L., & Piemeisel, L. N. The water requirement of plants at Akron, Colorado. Jour. Agr. Res. **34**: 1093–1190. *f. 1–16.* "15 Je" Jl 1927.

Shear, C. L., & Dodge, B. O. Life histories and heterothallism of the red bread-mold fungi of the *Monilia sitophila* group. Jour. Agr. Res. **34**: 1019–1042. *pl. 1–4.* "1 Je" Jl 1927.

Sherbakoff, C. D. Powdery mildew of muskmelon. Phytopathology **17**: 414–415. 15 Je 1927.

Sherff, E. E. *Isostigma peucedanifolium* (Spreng.) Less., a valid name. Bot. Gaz. **83**: 425. 22 Je 1927.

Showalter, A. M. Hermaphroditism in a dioicous hepatic. Proc. Nat. Acad. Sci. **13**: 369–372. 15 Je 1927.

Showalter, A. M. Studies in the cytology of the Anacrogynae. IV. Fertilization in *Pellia Fabbroniana.* Ann. Bot. **41:** 409–417. *pl. 19–21.* Jl 1927.

Shuhart, D. V. The formation and development of the pistillate flowers of the pecan. Oklahoma Agr. Exp. Sta. Bull. 163: 1–7. *illust.* F 1927.

Shull, C. A. Nature of the multiple seeded *Xanthium.* Bot. Gaz. **83:** 385–398. *f. 1–9.* 22 Je 1927.

Sinnott, E. W. A factorial analysis of certain shape characters in squash fruits. Am. Nat. **61:** 333–344. *f. 1–4.* Jl 1927.

Skinner, C. E. The effect of protozoa and fungi on certain biochemical processes when inoculated into partially sterilized soil. Soil Sci. **24:** 149–161. S 1927.

Small, J. K. Cacti. Jour. N. Y. Bot. Gard. **28:** 221–226. S 1927.

Small, J. K. The James palmetto—*Sabal Jamesiana.* Jour. N. Y. Bot. Gard. **28:** 181–185. *f. 1.* Au 1927.

Smith, I. S., Bergman, R. M., & Smith, G. V. Survey of trees and shrubs of Morgan County. Trans. Illinois Acad. Sci. **19:** 200–204. 1926.

Snow, L. M. Comparative study of the bacterial flora of wind blown soil. II. Atlantic coast sand dunes, Sandwich, Massachusetts. Soil Sci. **24:** 39–48. *f. 1, 2.* S 1927.

Solheim, W. G., Young, P. A., & Plunkett, O. A. A systematic presentation of new genera of fungi. Trans. Am. Micr. Soc. **46:** 187–207. Jl 1927.

Sorokin, H. Phenomena associated with the destruction of the chloroplasts in tomato mosaic. Phytopathology **17:** 363–380. *pl. 12–15.* 15 Je 1927.

Spoehr, H. A. Photosynthesis. 1–393. *f. 1–16.* N. Y., Chemical Catalog Co., 1926.

Standley, P. C. New plants from Central America. VIII, IX. Jour. Washington Acad. Sci. **17:** 245–254; 309–317. 19 My, 19 Je 1927.

Standley, P. C. Six new trees from British Honduras and Guatemala. Trop. Woods. 11: 18–22. 1 S 1927.

Hirtella guatemalensis, *Anneslia belizensis*, *Trichilina minutiflora*, *Eugenia Winzerlingii*, *Dipholis Stevensonii* and *Lucuma Heyderi*.

Standley, P. C. Some Rubiaceae collected in Mexico in 1841–43 by Frederick M. Liebmann. Jour. Washington Acad. Sci. **17**: 335–343. 19 Jl 1927.

Standley, P. C. Two new trees of the family Rubiaceae from Panama. Trop. Woods 11: 25–26. 1 S 1927.

Ixora rauwolfioides and *Chimarrhis parviflora*.

Stanton, T. R., & Dorsey, E. Morphological and cytological studies of an oat from Ethiopia. Jour. Am. Soc. Agron. **19**: 804–818. *f. 1–9.* S 1927.

Stapf, O. *Habranthus robustus.* Curt. Bot. Mag. **152**: *pl. 9126.* 8 Au 1927.

Native of Argentina?

Steagall, M. M. Some Illinois Ozark ferns in relation to soil acidity. Trans. Illinois Acad. Sci. **19**: 113–143. *pl. 1.* 1926.

Stevens, F. L. New tropical fungi. Mycologia **19**: 231–238. *pl. 18–21.* 1 S 1927.

Genera *Shropshiria*, *Clypeodiplodina*, *Chaetothyriopsis*, and several species described as new.

Stevens, F. L., & Young, P. A. On the use of the terms saprophyte and parasite. Phytopathology **17**: 409–411. 15 Je 1927.

Stewart, F. C. *Oedocephalum fimetarium* and *Peziza vesiculosa* var. *saccata* in mushroom beds. Mycologia **19**: 184–187. 1 Jl 1927.

Sudworth, G. B. Check list of the forest trees of the United States, their names and ranges. U. S. Dept. Agr. Misc. Circ. 92: 1–295. Mr 1927.

Svedelius, N. Alternation of generations in relation to reduction division. Bot. Gaz. **83**: 362–384. 22 Je 1927.

Svenson, H. K. Effects of post-pleistocene submergence in eastern North America. Rhodora **29**: 105–114. *f. 1.* 22 Je 1927.

Taylor, W. R., & Fogg, J. M., Jr. Notes on some fresh water algae from Newfoundland. Rhodora **29:** 160–164. 1 Au 1927.

Thaxter, R. Contributions towards a monograph of the Laboulbeniaceae. IV. Mem. Am. Acad. Arts & Sci. **15:** 431–580. *pl. 1–24.* S 1926.

Thaxter, R. Note on *Myxotheca hypocreoides* and its synonymy. Mycologia **19:** 160–164. *f. 1, 2.* 1 Jl 1927.

Thomas, H. E. Some chemical treatments of soil for the control of damping-off fungi. Phytopathology **17:** 499–506. 15 Jl 1927.

Thomas, W. Nitrogen metabolism of Pyrus Malus L. III. The partition of nitrogen in the leaves, one and two year branch growth and non-bearing spurs throughout a year's cycle. Plant Physiol. **2:** 109–137. *f. 1–4.* Ap 1927.

Thompson, W. P. The cytology of species hybrids in wheat. Sci. Agr. **8:** 56–62. *f. 1–4.* S 1927.

Thone, F. A stranded company. Am. For. & For. Life **33:** 532–534. *illust.* S 1927.
A group of relict species.

Tiffany, L. H., & Transeau, E. N. *Oedogonium* periodicity in the north central states. Trans. Am. Micr. Soc. **46:** 166–174. *f. 1–3.* Jl 1927.

Tingey, D. C. Smut studies preliminary to wheat breeding for resistance to bunt. Jour. Am. Soc. Agron. **19:** 655–660. Jl 1927.

Tisdale, W. H., & Griffiths, M. A. Variants in *Ustilago nuda* and certain host relationships. Jour. Agr. Res. **34:** 993–1000. 1 Je 1927.

Tisdale, W. H., Melchers, L. E., & Clemmer, H. J. Strains of kernel smuts of sorghum, *Spacelotheca Sorghi* and *S. cruenta.* Jour. Agr. Res. **34:** 825–830. *f. 1–4.* 1 My 1927.

Transeau, E. N. Vegetation types and insect devastations. Ecology **8:** 285–288. Jl 1927.

Trelease, W. Additions to the genus *Phoradendron.* Bull. Torrey Club **54:** 471–477. "Je" 2 S 1927.
Several species described as new.

Tucker, C. M. *Sabal causiarum* (Cook) Beccari; a new host of the coconut bud-rot fungus. Jour. Agr. Res. **34:** 879–888. *f. 1–4.* 1 My 1927.

Vacha, G. A., & Harvey, R. B. The use of ethylene, propylene and similar compounds in breaking the rest period of tubers, bulbs, cuttings and seeds. Plant Physiol. **2:** 187–194. *pl. 1.* Ap 1927.

Waksman, S. A. The soil and the microbe. Sci. Mo. **25:** 40–45. Jl 1927.

Wallace, R. H. The production of intumescences in Transparent apple by ethylene gas as affected by external and internal conditions. Bull. Torrey Club **54:** 499–542. *f. 1, 2 + pl. 3, 4.* "Je" 2 S 1927.

Ware, J. O. The inheritance of red plant color in cotton. Arkansas Agr. Exp. Sta. Bull. 220: 1–80. *f. 1–17.* Jl 1927.

Warner, H. H. Ancient yews of England. Am. For. & For. Life **33:** 519–521, 576. *illust.* S 1927.

Weatherby, C. A. A new *Polypodium* from Mexico. Am. Fern Jour. **17:** 91–94. *pl. 5.* S 1927.
P. sordidulum.

Wehmeyer, L. E. Cultural life histories of *Diaporthe* II. Mycologia **19:** 165–183. *pl. 13–15.* 1 Au 1927.

Wherry, E. T. Soil reaction of *Saxifraga Aizoon* on Mt. Katahdin. Rhodora **29:** 139–140. 18 Jl 1927.

Whiting, A. L., & Richmond, T. E. The relative rates of nitrification of different parts of sweet clover plants. Soil Sci. **24:** 31–38. Jl 1927.

Williams, R. S. Notes on Florida mosses. Jour. N. Y. Bot. Gard. **28:** 232–233. S 1927.

Williams, R. S. Notes of Louisiana mosses. Bryologist **30:** 31–33. "Mr" 15 Jl 1927.

Williams, R. S. An undescribed *Taxithelium* from Porto Rico. Bryologist **30:** 37–39. *pl. 2.* "My" 15 S 1927.
T. portoricense.

Wilson, O. The vanishing chestnut. Nat. Mag. **10:** 167–170. *illust.* S 1927.

Wilson, O. T. Asymmetrical variation in *Cocconeis scutellum* Am. Jour. Bot. **14:** 267–273. *pl. 30.* "My" 2 Je 1927.

Wilson, P. *Asarum canadense.* Addisonia **12:** 27. *pl. 398.* 30 Je 1927.
Native of eastern North America.

Woodroof, J. G., & Woodroof, N. C. The development of the pecan nut (*Hicoria pecan*) from flower to maturity. Jour. Agr. Res. **34:** 1049–1063. *f. 1–10.* 1 Je 1927.

Woodrow, J. W., Bailey, A. C., & Fulmer, E. I. The effect of ultraviolet radiation upon yeast culture media. Plant Physiol. **2:** 171–176. *f. 1.* Ap 1927.

Yeager, A. F. Determinate growth in the tomato. Jour. Hered. **18:** 263–265. *f. 10–12.* "Je" 10 S 1927.

Zeller, S. M. The yellow rust of raspberry caused by *Phragmidium imitans.* Jour. Agr. Res. **34:** 857–863. *f. 1–4.* 1 My 1927.

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